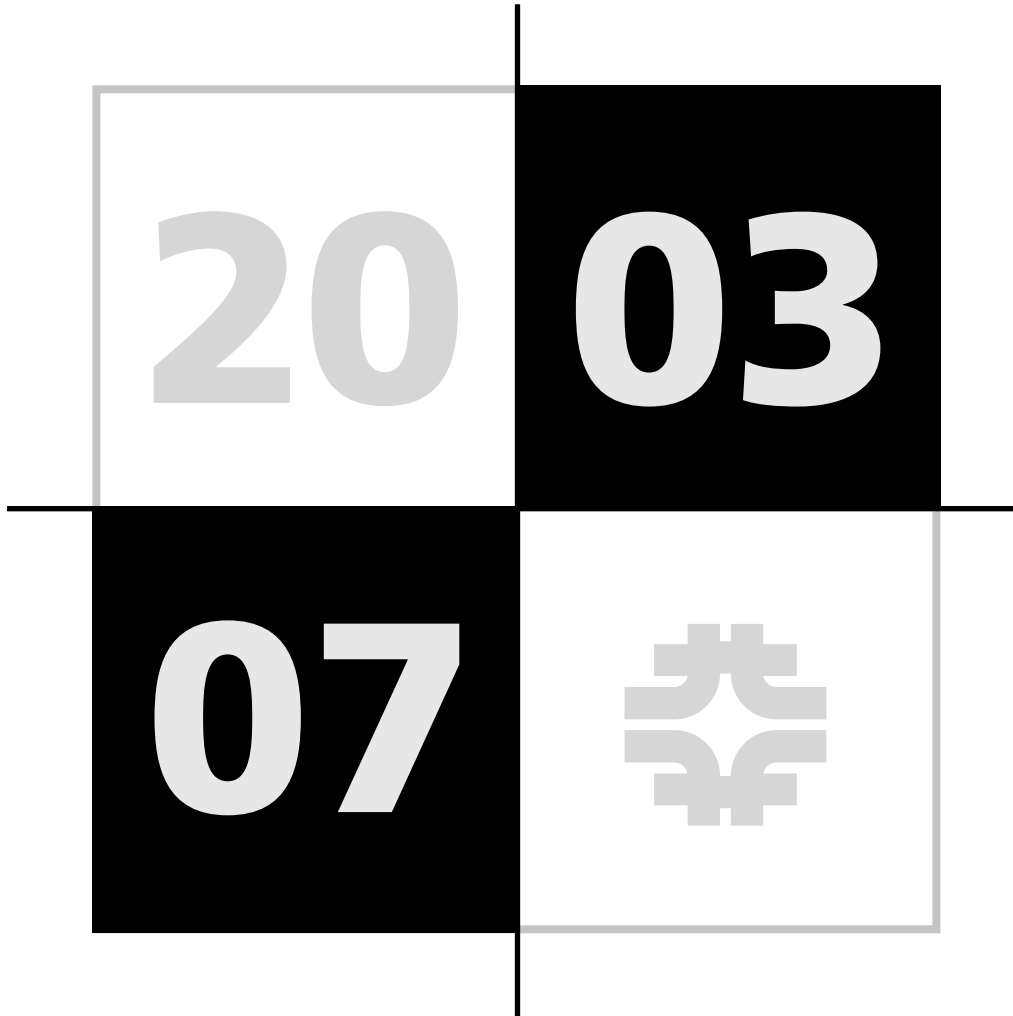


FERMILAB INSTITUTIONAL PLAN



FERMILAB INSTITUTIONAL PLAN

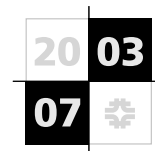
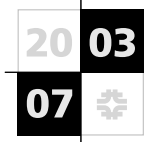


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From the Director



Fermilab Director Michael S. Witherell

Fermilab is dedicated to research in particle physics, with the goal of understanding the fundamental nature of matter, space, and time. We are the largest U.S. laboratory for particle physics, and we operate the Tevatron, the world's highest energy accelerator. Among the many scientific breakthroughs made at Fermilab are the discoveries of the top and bottom quarks, the two heaviest of the basic constituents of matter. Physicists from laboratories and universities all over the world come to Fermilab to do their research at the forefront of science.

We have great opportunities for discoveries ahead at Fermilab. We will be exploring new mass regions in Run II of the Tevatron, along with an excellent program in the fast-moving area of neutrinos. We are conducting unique experiments in particle astrophysics. We will be taking our first look at the TeV scale when the Large Hadron Collider begins operation at CERN, the European Particle Physics Laboratory. We will be conducting the best-of-class flavor physics experiments with BTeV and CKM. And we anticipate the prospects for hosting an international linear collider.

In carrying out its mission of basic research, Fermilab also advances the technology of accelerators. The impact of accelerators is steadily growing in medicine, materials research, structural biology, and nuclear physics, as well as in particle physics. Fermilab and other particle physics laboratories develop new accelerator technologies and techniques that are then transferred to other applications. We also train accelerator scientists, many of whom take their expertise into the applied fields that use accelerators.

Fermilab is committed to improving science and math education for American students, especially for those traditionally underrepresented in science. Each year, thousands of students and teachers visit Fermilab's site for workshops, field trips and classes.

Fermilab's site is open to the public, with due regard for security concerns. The laboratory offers many opportunities for recreational activities, such as attending a concert, experiencing the restored prairie, taking a bike ride, or enjoying one of the best bird-watching locations in the area.

We look forward to this new era of discovery for Fermilab.

Michael S. Witherell

Director

Fermi National Accelerator Laboratory

Mission and Roles



I. Mission Statement

As is the case from its founding in 1967, Fermilab's mission is to advance the understanding of the fundamental nature of matter and energy, by providing leadership and resources for qualified researchers to conduct research at the frontiers of high-energy physics and related disciplines.

II. Core competencies

Fermilab leads the nation in the construction and operation of large facilities for particle physics research, and in developing the underlying technology for high-energy physics research. The Lab's mission is built on a foundation of eight core competencies:

1. Operation of the world's highest-energy user facility—the Tevatron collider—for university scientists investigating the fundamental structure of matter and energy;
2. Accelerator research, design and development of the frontier machines that are necessary to keep the U.S. among the world leaders in high energy physics;
3. Magnet research, design and development with particular emphasis and expertise extending to leading-edge technology in both superconducting magnets and permanent magnets;
4. Detector design and development for the tracking and recording of trillions of high energy particle collisions;
5. High performance computing and networking to support high-energy physics in on-line data taking, storage, analysis and world-wide data sharing and physics collaboration (the World Wide Web was born from this last requirement by physicists);
6. International scientific collaboration, both at Fermilab and as a contributor to foreign laboratories such as CERN, in particular in assisting in the construction of the Large Hadron Collider and the Compact Muon Solenoid;
7. Construction and management of large scientific and technical projects, including the seven-year, \$260 million Main Injector accelerator, completed on time and on budget and dedicated in 1999;
8. Scientific education of graduate students, and additional science education programs for undergraduates and for K-12 students, with major support from non-DOE sources

III. Major User facilities

Fermilab, the world's highest-energy particle physics facility, welcomes more than 2,500 users (defined as "qualified researchers") from 214 institutions in 35 states and 29 foreign countries. These users have access to the world's best tools for particle physics research:

- The four-mile-circumference Tevatron, the world's most powerful particle accelerator, creates high energy proton-antiproton collisions and proton beams for fixed-target experiments. The third generation of quarks was discovered at the Tevatron: the Bottom Quark in 1977 and the Top Quark in 1995. The Tevatron is supplemented by the Antiproton Source, the world's largest producer of antimatter, which is used for proton-antiproton collisions and for research on antimatter; and by the Antiproton Recycler, the world's largest assembly of permanent magnet technology, which also increases the number of possible collisions in the Tevatron by recovering antiprotons that would previously have been discarded.

- The Booster, the first synchrotron in the accelerator chain at Fermilab, is 475 meters in circumference and accelerates protons from 400 MeV to 8 GeV in a period of 0.033 seconds. The Booster provides beam for the MiniBooNE experiment, and protons to feed the Main Injector in the Fermilab accelerator chain.

- The Main Injector, another powerful and efficient accelerator, can supply experiments on its own, as well as dramatically increase the number of collisions possible in the Tevatron. The two-mile-circumference Main Injector supplies beam for the NuMI (Neutrinos at the Main Injector) and CKM (Charged Kaons at the Main Injector) experiments.

- Two 5,000-ton collider detectors, CDF and DZero, each serving as an international collaboration of more than 500 university physicists;

- Fixed-target experiments, including the MINOS (Main Injector Neutrino Oscillation Search) and MiniBooNE experiments resolving the question of neutrino mass.

- The CMS (Compact Muon Solenoid) experiment at CERN, for which Fermilab serves as host for the U.S. component (US CMS) and as home for the US CMS research program involving nearly 400 scientists.

- The Lattice Gauge Theory Computing Facility, where approximately 60 user theorists work with the theory of quantum chromodynamics using teraflop computing power.



The Tevatron has achieved an all-time luminosity record of 3.61×10^{31} , with more improvements to come. When it began operations in 1983, the Tevatron's original design parameters put luminosity at 1×10^{30} .

Scientific Vision and Strategic Plan



I. Scientific Prospects for Run II: The role of the Tevatron in the world program of particle physics

The goal of particle physics is to understand the nature of matter, energy, space and time. The overarching question faced by the field is the scale of electroweak unification: What sets the mass scale of the weak interactions to be about 100 GeV? This question is addressed solely with colliders operating at the energy frontier.

Through the 1990s, four colliders operated at or near the energy frontier:

- The Tevatron at Fermilab, a proton-antiproton collider operating at a center of mass energy of 2,000 billion electron volts (GeV). The Tevatron has produced the discovery of the top quark, and measurements of top quark and W boson masses.

- The Large Electron-Positron collider at CERN, operating at a center of mass energy of 90-210 GeV. LEP has measured Z boson properties and W boson mass, and has set an upper limit on the Higgs mass.

- SLC at Stanford Linear Accelerator Center, an electron-positron collider operating at a center of mass energy of 90 GeV. SLC has measured Z boson properties.

- HERA at DESY in Germany, an electron-proton collider operating at a center of mass energy of 300 GeV. HERA has explored proton structure and Quantum Chromodynamics (QCD), and is less suited to electroweak physics than the other machines.

The Tevatron is the only collider able to address these central issues in the field of high-energy physics from 2002 to 2007. SLC and LEP have closed, and HERA will end its run in 2006. Additionally, the Tevatron's increased luminosity and slightly higher energy level make a new round of experimentation possible in five critical areas:

1. The fundamental scales of mass and energy: What causes the Higgs effect, breaking the electroweak symmetry and giving the W and Z boson their mass? Are all the precise measurements of the fundamental parameters consistent with the Standard Model, in which there is a single Higgs boson?

2. Supersymmetry and superstrings: Is there a supersymmetry that is broken at this scale? If so, is it connected with the quantization of gravity? Do new supersymmetric particles make up a significant component of dark matter?

3. Alternative new physics at the 1TeV scale: Are there observable effects of large hidden dimensions? Is there a new strong dynamics among the W and Z bosons?

4. Quarks and CP violation: Are all measurable examples of CP violation consistent with a single source?

5. QCD and the strong interactions: Are the strong interactions of quarks and gluons described by QCD at the highest energy? Do the quarks themselves have substructure at a smaller scale?

There will be important new results every year from the Tevatron.

Electroweak symmetry

The electromagnetic and weak interactions are connected by an electroweak symmetry. They are different manifestations of a single, electroweak interaction. The couplings are the same. However, the range of the weak interaction is very short, leading to its apparent weakness at low energies.

The masses of the intermediate W and Z bosons determine the range of the weak interaction. If the electroweak symmetry were unbroken, the masses of the W and Z would be zero, as for the photon. In the Standard Model, the masses are proportional to the average value of the Higgs field in the vacuum, which is 246 GeV.

What breaks the electroweak symmetry and gives masses to the W and Z?

This central issue has confronted particle physics for some time. In the Standard Model of particle physics, the Higgs field is distributed everywhere in space. The interaction of the W, Z, quarks, and leptons with this Higgs field gives them their mass. This quantum of this field is the Higgs boson, with a mass calculable from other measurements within the Standard Model, including the masses of the top quark and W boson.

Alternatives to the Standard Model

Although models with the standard Higgs boson explain the present data well, the existence of the Higgs has not been experimentally verified. It has not been observed. Something must generate the W and Z masses, and it must look like the Higgs field at low energies.

The Standard Model cannot be the whole story. The Higgs mass diverges quadratically without some other new physics. Alternative theories exist in which other phenomena cause the same effect as the standard Higgs boson.

Supersymmetry is the most-studied alternative, and is a necessary part of string theory. Supersymmetry cancels the divergence in the Higgs mass; naturally provides a dark matter candidate; provides a framework for the unification with gravity, and leads to the unification of gauge couplings. Extra dimensions can explain important features of the standard model, and would also have observable effects at Tevatron energies. A new strong dynamics, some variation of technicolor, can do the same.

The most important result at the Tevatron would be discovery of physics beyond that described in the Standard Model.

Other major areas of research at the Tevatron

CP violation and quark flavor physics:

Are all measurements of CP violation in the quark sector coming from a single CP parameter? We know there must be at least one other source of CP violation from the predominance of matter in the universe. Precise measurements of CP parameters and elements of the quark mixing matrix will provide a sensitive test for new sources of CP violation. A good measurement of B_s mixing is the most urgently needed result.

QCD – The strong interactions of quarks and gluons: We will look for non-pointlike structure of quarks and gluons using the highest-power microscope in the world by measuring jet production at high transverse energy. We will measure the quark and gluon

structure of the proton in regions that have been inaccessible. We will compare production and decay of heavy quarks with perturbative and lattice gauge calculations. We will determine the spectroscopy of new mesons and baryons containing heavy quarks.

The Tevatron research program

CDF and DZero, two large research collaborations, use the Tevatron collider as the source of their research program. Each collaboration is comprised of over 500 physicists from about 60 universities and laboratories around the world. Together these two collaborations include about 25% of the experimental particle physicists in the U.S. Approximately one-third to one-half of the members are from institutions outside the U.S.

Each collaboration, working with the Laboratory, has built and operates a multipurpose detector. Each massive detector contains state-of-the-art systems capable of observing up to 107 collisions per second and selecting about 50 of them to be written to tape. The events collected are reconstructed offline and used as the raw data that feed perhaps 100 separate experiments simultaneously.

As with the Hubble space telescope, a wide range of physics problems are addressed with the same apparatus.

Data samples past and present

Run I refers to the period 1992-6 in which an integrated luminosity of about 0.16 fb^{-1} was delivered to each detector.

*(Note: The event rate R in a collider is proportional to the interaction cross section σ_{int} and the factor of proportionality is called the **luminosity L** :*

$$R = \sigma_{int} L$$

The total number of events N over a period of time is then given by

$$N = \sigma_{int} \int L dt$$

*where $\int L dt$ is the **integrated luminosity**.)*

This is the sample which was used to discover the top quark and to produce many other important results. Run IIa refers to operations supported by the collider configuration envisioned during the Main Injector construction. The goal for integrated luminosity is to deliver about 2 fb^{-1} by 2005. Run IIa provides an order-of-magnitude larger data sample. Run IIb refers to operations in the period starting around 2005, after a number of hardware upgrades to accelerators and detectors. The goal for integrated luminosity is to deliver approximately $10\text{-}15 \text{ fb}^{-1}$ by the time the LHC experiments are producing physics.

The scientific record to date

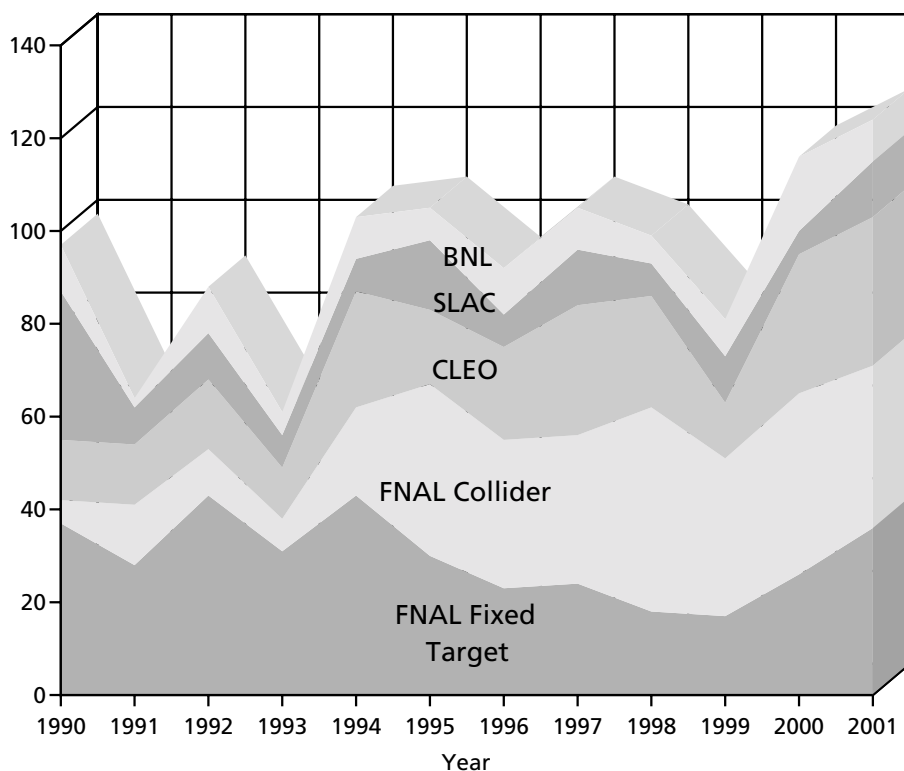
The detector collaborations have compiled impressive results in scientific publications, both before and during Run I. We can expect similar if not greater results from Run II.

The CDF Collaboration (1988-2002) has published 158 papers in Physical Review Letters, 82 papers in Physical Review, and 61 papers in Nuclear Instruments and Methods. Of this total, 24 of these publications each have over 100 citations in the SPIRES database: six papers on the top quark, including the two papers on the discovery which each have over 500 citations; seven papers on QCD; five papers on W and Z bosons; two on Supersymmetry searches; one on other exotic searches; one on

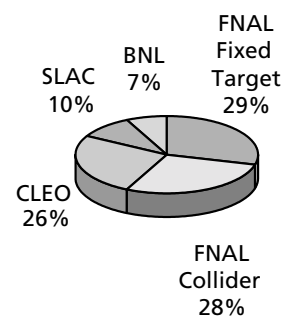
CP Violation, and two on instrumentation. This total represents a greater number of cited results than any other HEP experiment. In addition, 188 Ph.D. theses have been completed on CDF research.

The DZero Collaboration (1994-2002) has published 69 papers in Physical Review Letters; 14 papers in Physics Letters; 31 papers in Physical Review, and 38 papers in Nuclear Instruments and Methods. Among these publications, five papers each have more than 100 citations in the SPIRES database: the two top quark papers, including the discovery paper with over 500 citations; one on a Supersymmetry search; one on QCD, and one on instrumentation. Also, 128 Ph.D. theses have been completed on DZero research.

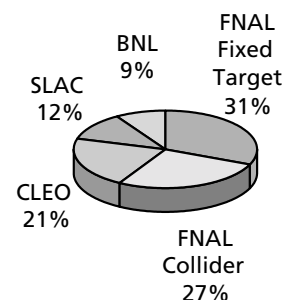
Experimental HEP Publications 1990-2001



2001



1990-2001



Experimental HEP Publications 1990-2001

All Years	FNAL	Fixed Target	Collider	CLEO	SLAC	Fixed Target	e+e-	BNL	HEP	Heavy Ions	Total
1990	42	37	5	13	32	32	0	10	10	0	97
1991	41	28	13	13	8	8	0	2	2	0	64
1992	53	43	10	15	10	10	0	10	10	0	88
1993	38	31	7	11	7	4	3	5	5	0	61
1994	62	43	19	25	7	3	4	9	3	6	103
1995	67	30	37	16	15	5	10	7	1	6	105
1996	55	23	32	20	7	3	4	10	9	1	92
1997	56	24	32	28	12	4	8	9	6	3	105
1998	62	18	44	24	7	4	3	6	5	1	99
1999	51	17	34	12	10	5	5	8	5	3	81
2000	65	26	39	30	5	1	4	16	12	4	116
2001	71	36	35	32	12	0	12	9	9		124
Total	663	356	307	239	132	79	53	101	77	24	1135
<mean>	55.3	29.7	25.6	19.9	11.0	6.6	4.4	8.4	6.4	2.2	91.9
Sigma	10.8	8.7	13.8	7.6	7.2	8.4	3.9	3.4	3.5	2.4	17.3

Phys. Lett. B, Phys. Rev Lett., Phys. Rev. D, Euro Phys J, Nucl Phys B

Physics prospects in Run II

The most important new results will come from precise measurements of fundamental quantities and from discoveries (or definitive exclusion) of new physical phenomena that indicate new physics beyond the Standard Model. Precise measurements of fundamental quantities, usually to look for inconsistencies that would indicate a breakdown in the Standard Model, include measurements of the top quark and W boson masses and couplings; and measurements of the parameters needed to test new sources of CP violation.

Possible discoveries include the Higgs boson or any new physics (that is, physics beyond the present theory) at the 1 TeV mass scale. These discoveries would include the Higgs boson; Supersymmetry, either through seeing supersymmetric particles or one of the five Higgs bosons that exist in supersymmetric models; extra dimensions; new dynamics (technicolor, new gauge bosons), and quark or lepton compositeness.

The Tevatron program has the potential for a discovery that would change the direction of particle physics. It would clarify the parameters needed for future experimentation including a future electron-positron Linear Collider.

Chart: Higgs Search

The plot below shows the integrated luminosity needed to reach three stages for each value of the Higgs mass:

■ 95% confidence level upper limit if no signal is seen;

■ a 3σ signal above background, conventionally called "Evidence;"

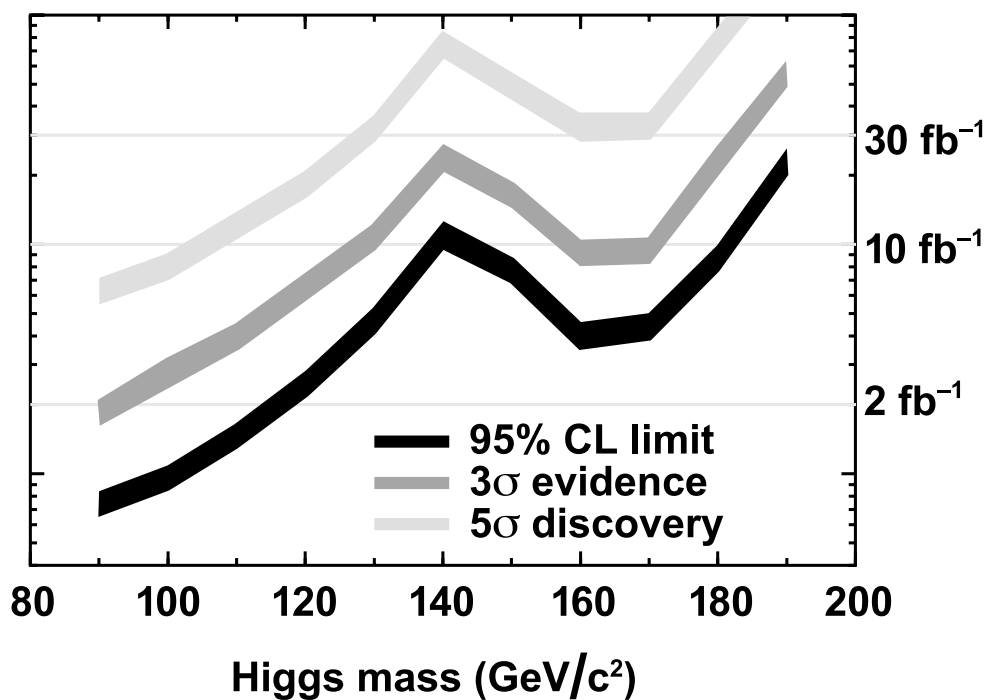
■ a 5σ signal above background, conventionally called "Discovery."

For a Higgs mass of ~ 115 GeV, the value of the LEP "hint":

■ upper limit @ $\sim 2 \text{ fb}^{-1}$

■ evidence @ $\sim 5 \text{ fb}^{-1}$

■ discovery @ $\sim 15 \text{ fb}^{-1}$



Whether Fermilab physicists will find the Higgs boson depends on its mass and the number of proton-antiproton collisions created in the Tevatron. The accumulation of two inverse femtobarns (fb^{-1}) of data during Run IIa by both CDF and DZero, corresponding to 2×10^6 million collisions by the end of 2003, would be sufficient to rule out at the 95% confidence level the $115 \text{ GeV}/c^2$ Higgs proposed by CERN experiments. If there exists a Higgs with that mass, it will take about 15 fb^{-1} , the goal of Run II by 2007, to claim a 5σ discovery. This chart does not take into account all Higgs signatures and the possibility that the Higgs has higher interaction strength than suggested by the standard theory, both of which could speed up discovery.

Science prospects increase with size of the data sample. Every doubling of the integrated luminosity makes possible a new round of important physics results. This has been true in the past at the Tevatron, LEP, and other colliders operating at the energy frontier. At a hadron collider, this effect is enhanced because the effective center of mass energy rises with luminosity.

The sensitivity of the Higgs search, as for any search for a rare signal above background, is proportional to the square root of the luminosity. The following pages contain a short list of physics highlights expected at given values of the integrated luminosity. Each entry represents a major advance. This is a small selection of the physics observations that will be produced. Some items represent a whole program of new results. More detail is given for the near future. Only a few topics are considered in the longer run, since much of the physics program then depends on results to come in the next few years. All of the "possible discoveries" listed are of the scale that would change the direction of particle physics. Obviously, if any of them were realized, they would change the direction of the program dramatically.

Prospective physics highlights at a range of luminosities

At 0.1 fb⁻¹:

With a data sample of this size, there will be many new physics results. The new detectors have increased capability and the collider energy has changed from 1.80 to 1.96 TeV, significantly increasing cross sections for high-mass states. We can anticipate measurements of the cross-sections for the top, bottom, and charm quarks, W and Z, and jets. This range would mark the start of a broad program of measurements on particles containing the bottom quark, including spectroscopy, lifetimes, and mixing

At 0.3 fb⁻¹:

At this point, major new results will appear in every area of research at the Tevatron, including the first opportunity to identify signals of new physics. We can anticipate measurements of the top quark mass with twice the present precision, and measurements of B_s mixing, which are critical for CP violation tests. In areas of new physics, we might discover extra dimensions with a scale of 1.6 TeV; and we can expect to confirm or eliminate new physics indicated by Run I observations of rare events. In QCD, we can expect measurements of the jet spectrum at highest transverse energy, probing for a substructure of quarks

At 1 fb⁻¹:

In electroweak physics, we can expect measurements of W magnetic moment; signals for production of 2W's and W+Z events, and measurements of top quark properties with 1,000 top events per experiment. In Supersymmetry, we might discover supersymmetric particles and possibly one of the five supersymmetric Higgs bosons. The possible discovery of technicolor would highlight other new physics. We can explore CP violation with measurements of the CP angle γ to 9° using B and B_s decays.

At 2 fb⁻¹:

At this point the full discovery potential of the Main Injector/Recycler upgrade is realized. In the electroweak sector, we anticipate precise tests of the Standard Model and prediction of the Higgs mass. We can measure W boson mass to greater precision than the LEP experiments could achieve. We can make precise measurements of top quark properties of mass and decay modes. We can achieve a 95% exclusion of a Higgs boson with mass of 115 GeV. We would observe supersymmetric squarks and gluinos, if gluino masses are below 400 GeV. We would observe supersymmetric neutralinos, if their mass is below 180 GeV. In CP violation and the Bottom quark sector, we can achieve measurements of the decay mode

$B_d \rightarrow K^* \mu^+ \mu^-$, a mode sensitive to many modifications of the Standard Model.



The box-shaped magnets for the Recycler Ring, designed to store antiprotons close to the speed of light, sit atop the Main Injector, which accelerates protons and antiprotons from 8 to 150 GeV.

At 4 fb⁻¹:

Here, we can achieve a 95% exclusion of a standard Higgs boson up to 125 GeV. We see the possibility of discovering supersymmetry in a large fraction of parameter space for minimal supersymmetry, along with the possible discovery of a supersymmetric Higgs signal for a mass of 150 GeV. At this level, a series of very precise measurements of fundamental parameters is needed to test the hypothesis that CP violation comes from a single source:

γ , $\sin(2\beta)$, and V_{ts}

At 8 fb⁻¹:

Here, we might expect 3σ evidence for a standard Higgs with a mass less than 122 GeV, and 95% exclusion of a standard Higgs for masses below 135 GeV, or from 150 GeV to 180 GeV. We see the possible discovery of supersymmetric particles in a larger range of supersymmetric models, with a 95% exclusion of the minimal supersymmetric Higgs in the maximal mixing model.

At 15 fb⁻¹:

At this pinnacle of luminosity, we anticipate $4-5\sigma$ evidence for a standard Higgs with a mass of 115 GeV, with 95% exclusion of a standard Higgs for all masses below 185 GeV. We can see the possible discovery of supersymmetric particles for gluino masses up to 600 GeV, and the possible discovery of a supersymmetric Higgs boson A with mass up to 200 GeV. In the electroweak sector, we can achieve top quark mass measurements with an error of 1.3 GeV (compared to 5 GeV today), and W mass measurements with an error of 15 MeV (compared to 40 MeV today).

Alternatively, if we observe nothing, the very structure of our understanding thus far is in question.

Summary

The questions addressed at the Tevatron include most of the central questions in particle physics. The Tevatron is the only collider able to address the central problems in the field from 2002 to 2007. The Tevatron program has the potential for a discovery that would change the direction of particle physics.

The most important result at the Tevatron would be discovery of physics beyond that described in the Standard Model. Such a discovery could come well before the integrated luminosity is sufficient to observe the Higgs boson.

There will be important new results every year from the Tevatron. Every doubling of the data sample makes possible a new round of important physics results.



The Main Injector (foreground), two miles in circumference, will greatly enhance the discovery potential of the four-mile Tevatron (background) during Collider Run II.

II. Neutrino Physics: Ready to step beyond the Standard Model?

Scientists at Fermilab have found a surprising discrepancy between predictions for the behavior of neutrinos and the way the subatomic particles actually behave. Although the difference is tiny, it has potentially far-reaching implications.

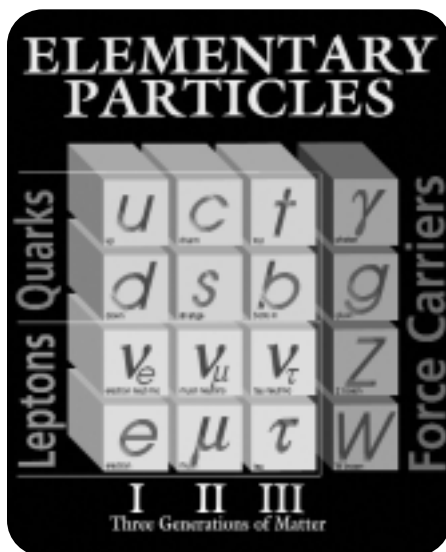
Experimenters at Fermilab's NuTeV (Neutrinos at the Tevatron) experiment measured the ratio of two types of particles—neutrinos and muons—emerging from high-energy collisions of neutrinos with target nuclei. The results of generations of particle experiments with other particles have yielded precise predictions for the value of this ratio, which characterizes the interactions of particles with the weak force, one of the four fundamental forces of nature. For other elementary particles, including the quarks and electrons of ordinary matter, the predictions seem to hold true.

But, to the NuTeV experimenters' surprise, when they looked at neutrinos with comparable precision, neutrinos did not appear to fall into line with expectations. The quantity, $\sin^2\theta_W$ tells the strength of the interaction of neutrinos with the Z boson, one of the carriers of the weak force. The predicted value was 0.2227. The value found by NuTeV was 0.2277, a difference of 0.0050.

The NuTeV result doesn't quite fit the Standard Model, the very precise theoretical picture that physicists have developed to explain fundamental particles and forces and their interactions. In particle physics, such a result may be the harbinger of new particles, new forces and new ways of describing nature. The experimenters reported a three-sigma discrepancy in $\sin^2\theta_W$, which translates to a 99.75 percent probability that the neutrinos are not behaving like other particles.

The result seems to say that neutrinos behave very differently from other particles. Experimenters using the Large Electron Positron at CERN, the European Particle Physics Laboratory, have measured this same neutrino interaction in a different particle reaction. They saw the same discrepancy with less certainty.

Fermilab's ongoing program to investigate neutrino anomalies, and the question of neutrino mass, consists of two experiments: MiniBooNE, the short-baseline experiment using beam from the booster accelerator; and MINOS, the long-baseline experiment that will draw beam from Fermilab's Main Injector accelerator, then send a beam of neutrinos through the earth to an underground detector in Minnesota, some 450 miles away.





Janet Conrad of Columbia University hopes the MiniBooNE experiment will soon add neutrino discoveries to the long list of Fermilab research milestones.

MiniBooNE ready to take data

Marking the completion of its detector on May 3, 2002 with a final cup of ultra-pure mineral oil—the last of 250,000 gallons of this translucent liquid—MiniBooNE is embarking on the quest to repeat the landmark neutrino oscillation result of the Liquid Scintillating Neutrino Detector at Los Alamos National Laboratory. MiniBooNE's goals are to confirm (or refute) the LSND observation with much better statistical precision (thousands of events compared to tens of events in LSND), and accurately determine the

oscillation parameters ($\sin^2\theta\omega, \Delta m^2$), of the oscillations.

The accelerator-based LSND experiment produced evidence of neutrino oscillations. Confirming that result—accelerator-produced neutrinos that change from one flavor to another—would also indicate the existence of an additional flavor or type of neutrino, beyond the three now known. A fourth neutrino would represent another crack in the Standard Model of particle physics, and both a milestone and a challenge for particle physicists.

The MiniBooNE beam came to life in late April, with a stream of particles originating in the Booster accelerator and traveling about three-fourths of the way down the 680-foot beam pipe to a temporary target. The attempt began late on April 26, with first beam recorded at 4 a.m. on April 29.

In one year, MiniBooNE will transport more protons than in all 17 years of the Fixed-Target Program at Fermilab. To control the beam, the Beams Division's External Beams department has built two concepts into the MiniBooNE operation. The first is "auto-tune," an automated tuning program to keep the beam properly positioned inside the beam pipe.

The second is "e-berm," an electronic monitoring system intended to help minimize beam loss. Earthen berms are built over accelerators to absorb particles from beam loss; "e-berm" aims at limiting the need for an earthen berm by limiting losses. The concept has been used before at the lab, but this system is an entirely new one developed at Fermilab. The system uses toroid magnets for measurements, one at the beginning of the beam line and one at the end. If the measurements are the same at both ends, the beam is intact; if not, beam losses are immediately tracked down and corrected.

MiniBooNE and External Beams will study and tune the beam, de-bug the instrumentation, and develop the process of moving the focusing horn in and out of the target area. With the temporary target moved out, beam will be sent all the way down the line to the horn and permanent target to produce the experiment's first accelerator-generated neutrinos. In its operational stage, MiniBooNE will produce neutrinos by drawing on the 8 GeV beam from the revamped Booster accelerator. With the detector completed, MiniBooNE has begun tracking cosmic ray events, anticipating final beam tests and then the first neutrino results later in 2002.

Many of the MiniBooNE detector's photomultiplier tubes were originally used at LSND, as were some of the electronic components. Los Alamos made critical contributions to the phototubes, electronics, DAQ, oil plumbing and detector design.



The cavern housing the detector for the Main Injector Neutrino Oscillation Search, where nearly half of the projected 486 detector planes have been assembled and installed. The mural is 59 feet wide and 25 feet high.

NuMI/MINOS records first cosmic ray muon

The MINOS detector saw its first upwardgoing muon on March 26, 2002.

The MINOS detector is currently under construction half a mile underground in a former iron mine in Soudan, Minnesota. The project has installed more than half of the 486 slices of steel and scintillator that make up the detector.

When the MINOS collaboration begins experimental operations in 2005, it will detect neutrinos sent to Minnesota from the Fermilab Main Injector. The first muon event resulted from a cosmic ray in the atmosphere. Even in its unfinished state, the detector can “see” such particles generated by cosmic rays.

The sighting of an upward-going muon means that the MINOS detector can distinguish that specific kind of track the many thousands of tracks of muons going the other way—not upward through the earth, but downward from the sky. For every upward-moving track, the detector observes about 10,000 tracks of downward-moving muons. It is a great test of the pattern-recognition capabilities of the MINOS detector that it could pick out the needle of the upward-moving track from the haystack of downward moving muons.

The first plane was installed in July 2001. A staff of 31 technicians is working on the installation, alongside MINOS physicists. There are usually about 12 physicists and students underground at Soudan each week. The MINOS collaboration expects to energize the first of the two MINOS coils in July 2002, with the first half of the detector assembled. The detector should be completed in the summer of 2003.

The MINOS experiment, using facilities built by the Neutrinos at the Main Injector (NuMI) Project at Fermilab, will seek evidence for an extremely small mass for these subatomic particles.

To detect such a small quantity (mass difference squared) requires observing the neutrinos after they traverse a very long path. An experiment which interposes a long distance between the source of the neutrinos and the neutrino detector is called a long-baseline experiment. Physicists have long recognized the possibilities for new physics insights offered by long-baseline neutrino oscillation experiments. Finding a neutrino source of sufficient intensity proved difficult, however. Like the beams from flashlights, beams of neutrinos fade out as they diverge over long distances. However, the new Fermilab Main Injector accelerator, which began operating in 1999, has the capability to provide intense neutrino beams, even at the distance required for a long-baseline experiment.

The new Main Injector will serve as the neutrino source for the MINOS experiment. The experiment's long baseline will begin at Fermilab, 40 miles west of Chicago, and end deep in a former iron mine in Soudan, a village in northern Minnesota, where MINOS will place its neutrino detector—735 kilometers, or about 450 miles, from the source.

When the neutrinos arrive from Fermilab (a trip that will take 0.0025 seconds) they will encounter a massive detector, 5400 metric tons of iron studded with plastic-strip particle detectors, 800 meters beneath the Minnesota woods. Because neutrinos interact so rarely with other particles, only huge masses of material offer the chance of creating—and

observing—an occasional interaction as the beam of neutrinos sails through. The detector will measure interactions of the neutrinos from the Fermilab beam, detecting about 9,000 neutrino interactions each year, out of five trillion neutrinos that pass through. A sandwich of steel and plastic scintillator detectors will measure the energy produced in the particle interactions and record the momentum of outgoing muon particles by tracking their paths as they go through the magnetized steel plates. MINOS experimenters will measure and compare the properties of neutrinos as they leave the Fermilab site, one kilometer from the source, and when they arrive at the detector in Sudan.

A difference between characteristics of the neutrino interactions in these two detectors would provide evidence for oscillation between types of neutrinos, and hence of neutrino mass. MINOS experimenters will build the near detector as a small-scale replica of the far detector, to make the two as similar as possible.

Neutrino mass

We are entering an era in experimental neutrino physics whose main thrust will likely be twofold: better understanding of the nature of the neutrino, i.e., a study of the neutrino properties, and use of the neutrino in astrophysics and cosmology as an alternative window on the universe, to supplement investigations with electromagnetic radiation. The MINOS experiment, which addresses the subject of neutrino oscillations, will make important contributions to the first part of this program.

Neutrinos are among the fundamental constituents in nature. The space around us is permeated with neutrinos which are relics of the Big Bang, with about 110 neutrinos per cm^3 for every neutrino flavor. But our knowledge of the neutrino's properties lags far behind our knowledge of other elementary constituents, for example, the charged leptons. A few examples will illustrate this point, quoting lepton values from the Particle Data Group:

- We do not know whether neutrinos have mass; our current information gives us only upper limits ranging from a few eV for ν_e to some 20 MeV for ν_τ . We can contrast that with a fractional mass error of about 3×10^{-7} for the electron and muon and about 2×10^{-4} for the tau.

- We do not know if neutrinos are stable or decay, either into neutrinos of other flavors or into some new, as yet undiscovered, particles. In contrast, we know that the electron is stable, and we know the muon lifetime with a fractional error of 2×10^{-5} and the tau lifetime at the level of 0.5%.

- Finally, we do not know if the neutrinos have electromagnetic structure, for example a magnetic moment. The electron magnetic moment is known with a precision of about one part in 10^{11} , and the magnetic moment of the muon to one part in 10^8 .

These are only a few examples of our incomplete picture of the basic nature of neutrinos, but they are sufficient to demonstrate that almost half a century after their discovery, neutrinos are still poorly understood. Because of their fundamental nature, we cannot profess to understand our universe without understanding neutrinos.

The study of neutrino oscillations offers potentially the most sensitive means to search for and to measure neutrino masses (or, to be precise, neutrino mass-squared differences). Observation of a nonzero neutrino mass, which would follow directly from the observation of neutrino oscillations, would be a clear example of a breakdown of the Standard Model and thus an indication of physics beyond it. Many of the popular extensions of the Standard Model do indeed predict nonzero neutrino masses and the existence of neutrino oscillations. Furthermore, neutrino oscillations are more than just an attractive theoretical concept: the existence of the phenomenon is strongly suggested by several experimental observations:

- a) The need for dark (i.e., non-shining) matter is based mainly on three phenomena: the motion of galaxies within clusters of galaxies, the rotational curves for stars in spiral galaxies, and the successes of inflationary Big Bang cosmology which predicts that the density of the universe equals the so-called critical density. Neutrinos, since they are present in abundance everywhere, could account for at least a part of the dark matter if they have finite mass.
- b) The solar neutrino deficit, i.e., the observation of fewer sun-originated neutrinos on earth than is expected from the known solar luminosity.
- c) The atmospheric neutrino anomaly, i.e., a measured ν_μ / ν_e ratio for neutrinos from cosmic ray interactions in our atmosphere which is significantly smaller than predicted. The hypothesis that this anomaly is caused by neutrino oscillations is strongly supported by the observation of an up-down asymmetry in the atmospheric ν_μ flux by the Super-Kamiokande Collaboration, as well as by their studies of upward going muons.

- d) The apparent observation of $\nu_{e(\text{bar})}$ in an almost pure ν_μ beam in the Los Alamos LSND experiment.

The MINOS experiment can explore a large region in oscillation parameter space. Furthermore, it can confront directly and conclusively the atmospheric neutrino anomaly and should be able to check the validity of the oscillation interpretation for the LSND effect.

The underlying principle behind neutrino oscillations is the fact that, if neutrinos have mass, then a generalized neutrino state can be expressed either as a superposition of different mass eigenstates or of different flavor eigenstates. This is mainly a restatement of a well-known quantum mechanics theorem that, in general, several different basis vector representations are possible, with the different representations being connected by a unitary transformation.

Other well-known examples of this principle in particle physics are the $K^0 / K^{0(\text{bar})}$ system (strong interaction and weak interaction eigenstates) and the quark system (weak interaction and flavor eigenstates connected by the CKM matrix). From the study of e^+e^- annihilations at the Z_0 peak, we know that there are only three light neutrino flavor eigenstates. Accordingly, the most likely situation is that we have three mass eigenstates and that the connecting unitary matrix is a 3x3 matrix. This is not rigorously required since we could have states with $m_\nu > m_Z/2$ or flavor states that do not couple to the Z_0 . There has recently been significant theoretical effort to see whether such mechanisms could explain some of the anomalous effects seen in neutrino experiments.

III. Fermilab and the LHC: A major stakeholder in the physics to come

The U.S. has a \$531 million commitment to provide accelerator and detector components for the Large Hadron Collider, which is under construction at CERN, the European Particle Physics Laboratory in Geneva, Switzerland, and which will begin operations later this decade. Fermilab will be the host to about 400 U.S. scientists participating in the Compact Muon Solenoid (CMS) collaboration.

LHC is projected to achieve a center-of-mass energy of 14 TeV, some seven times the center-of-mass energy at the Tevatron, and about 10 times the effective constituent energy of the machine it replaces at CERN, the Large Electron-Positron Collider. In mounting proton-proton collisions, LHC will have beam crossings every 25 nanoseconds (compared to 396 nanoseconds now at the Tevatron, and 132 nanoseconds by the end of Run II), anticipating 20 to 30 collisions at every beam crossing. The luminosity, a measure of the collision rate, will reach $10^{34} \text{ cm}^{-2} \text{ sec}^{-1}$, about 100 times that of the Tevatron.

Because of Fermilab's role in construction of LHC components, the U.S. physics community will be positioned for a major role in the emergent physics when LHC begins operating later this decade.

Accelerator efforts

The US LHC Accelerator Project is led by Fermilab and carried out by three U.S. national laboratories: Fermilab, Brookhaven National Laboratory (BNL) and Lawrence Berkeley National Laboratory (LBNL). The project focuses on the four Interaction Regions (IRs) and the radio-frequency straight section of the LHC Accelerator, testing of superconducting cable for the main LHC magnets, and accelerator physics calculations.

Fermilab, in collaboration with LBNL and BNL, is responsible for providing CERN with integrated inner triplet magnet systems for the IRs, which focus and bring the two proton beams into collision at the interaction points. The inner triplet systems consist of high-gradient quadrupoles provided both by Fermilab and the KEK laboratory in Japan, correction coils provided by CERN, dipole magnets provided by BNL, cryogenic feedboxes provided by LBNL, and absorbers provided by LBNL to protect the superconducting magnets from the collision debris. In addition to building half of the quadrupoles, Fermilab is responsible for the integration of the Fermilab, KEK and CERN provided magnets into three different types of quadrupole-corrector assemblies, insertion of these into cryostats, and the final measurements and tests of these assemblies.



Q2P1, also known as "Jessica," is a full-scale prototype of the advanced superconducting quadrupole magnets being built at Fermilab for the Large Hadron Collider at CERN. Superconducting magnet technology represents a vibrant research and development effort at Fermilab.

The superconducting quadrupole magnets, which provide final focusing of the LHC beams at the interaction points, are one of the most challenging components of the machine. They must provide a field gradient of up to 215 Tesla/meter over a 70 mm aperture. They operate at 1.9 K, under heavy heat load due to secondary particles from beam-beam collisions. The LHC performance depends critically on their field quality. Following an intensive R&D program, in which nine model magnets and one full-scale prototype were built and tested, the inner triplet quadrupoles for the LHC are now in production at Fermilab. Four of the 18 quadrupoles that Fermilab will build are complete and two more are in production.

The first KEK and CERN provided magnets have arrived at Fermilab. The first quadrupole-corrector assembly, consisting of two Fermilab quadrupoles with a CERN correction coil, is being readied for insertion into its cryostat and will be tested by the end of the summer. Production and testing of the quadrupoles will continue for the next two and one-half years, and all inner triplet quadrupoles will be delivered to CERN for installation in LHC by the end of 2004. The US LHC Accelerator Project is more than 75 percent complete, and is proceeding on schedule.

The development, construction and testing of these very challenging magnets for LHC helps to ensure that Fermilab and the U.S. High Energy Physics program remain at the cutting edge of superconducting magnet technology. The lab's work with CERN (and KEK) on the construction of the LHC accelerator is an important step forward in international collaboration in large science projects, which will be crucial for the construction of future large accelerator facilities.

Fermilab is now preparing to extend this collaboration into the commissioning and operational periods of the LHC, and are beginning work with CERN to increase the luminosity of the LHC in order to extend its scientific reach. The US LHC Accelerator Research Program, which will be carried out by the same three U.S. national laboratories under Fermilab's leadership, will focus on the commissioning of the LHC, accelerator physics experiments and calculations, R&D for quadrupoles of even higher performance than those now under construction for the inner triplet systems, and the development of advanced beam instrumentation and diagnostics.

This program will further develop the U.S. laboratories' capabilities, so that the U.S. can be the leader in the next generation of hadron colliders; it will serve as a vehicle for U.S. accelerator specialists to pursue their research; and it will train future generations of physicists on some of the most advanced problems in accelerator physics.

The Compact Muon Solenoid detector, and US CMS

The Compact Muon Solenoid is a general-purpose proton-proton detector designed to run at the highest luminosity at the LHC. It is also adapted for studies at the initial lower luminosities. The main design goals of CMS have been to achieve the highest performance muon system, electromagnetic calorimeter and central tracking system, and a hermetic hadron calorimeter. The CMS detector is built around the largest superconducting magnet in the world, a 12-meter-long and 7-meter-diameter cylindrical coil called the Compact Muon Solenoid. The complete CMS detector stands 15 meters high and almost 22 meters long, and weighs about 12,500 tons.

Fermilab is involved in US-CMS as both the host laboratory and as one of the 37 collaborating institutions. The US-CMS project is approximately 65 percent complete and proceeding on schedule. Fermilab and project management have been planning the transition to the CMS research program for two years, and the effort was baselined by a review in April 2002. Fermilab is working to integrate the CMS research program into the laboratory, and the first Ph.D. from US-CMS was recently awarded for work on the alignment of the endcap muon chambers.

Fermilab has been responsible for construction of the Hadron Calorimeter for CMS. The completed CMS HCAL barrel and endcap weigh about 1600 tons, and most of components are copper. It represents the heaviest copper alloy structure ever built. HCAL is similar in design to the end plug calorimeter at Fermilab's CDF detector, and the proposed SDC calorimeter at the SSC. The magnetic field inside CMS will be 4 Tesla, double the strength of Fermilab's DZero detector (2T) and nearly three times that of CDF (1.4T). The higher magnetic field produces more bending, and thus higher differentiation, in particle tracks.

CMS has an all-silicon tracker, with a critical production role for Fermilab's Silicon Detector Facility, already setting new standards with Run II detectors. The unique facility is producing silicon strip modules for the CMS tracker outer barrel, and silicon pixel disks for the CMS forward tracking system.

The endcap muon chambers, or cathode strip chamber (CSC) system, machined and assembled at Fermilab Lab 8 and MP9, comprise the largest system of its kind anywhere, by a factor of 10. There are nearly 500 chambers with six layers in each chamber.

A revised design for the forward tracker has three disks at each end, for a total of 43 million pixels. Arranged like turbine blades on the disk, each individual detector is 8 mm x 10.45 mm, with a 52x53 pixel array, and is equivalent to 380K transistors. The pixel array will produce a resolution up to 15 microns (millionths of a meter). Among these detectors' responsibilities: putting a time stamp on the bunch crossings, which will 25 nanoseconds (billionths of a second) apart.

Fermilab's microelectronics group has developed two radiation-hard chips for HCAL, one (QIE) based on earlier chips for CDF and KTeV and the other (CCA) an entirely new design. QIE takes signals from photomultiplier tubes and digitizes them over a wide dynamic range at high frequency. CCA takes output data from QIE chips and provides phase adjustment for data, and interfaces to the DAQ system.

Fermilab also will serve as the regional computing center for US CMS, which includes nearly 400 scientists from 37 institutions across the country (the worldwide CMS collaboration numbers approximately 1,800 scientists in 144 institutions). Fully functional prototypes of the software are already in use, and Fermilab has simulated more than four million Monte Carlo events for US CMS.

Fermilab is working to integrate the CMS research program into the laboratory. We will make it possible for US CMS members to conduct research here with the same tools and access to data as at CERN. We are devoting one floor of Wilson Hall to US CMS, with offices for Users and a virtual control room.

IV. Particle Astrophysics:

Mapping the skies, hunting for dark matter, tracking down the highest-energy cosmic rays

Fermilab has special capabilities to mine the growing convergence between particle physics and astrophysics. The Particle Physics Division's Astrophysics Group has a track record of making a big impact with modest resources: with the Sloan Digital Sky Survey, the Pierre Auger Observatory and the Cryogenic Dark Matter Search.

SDSS: Mapping the sky

Fermilab is responsible for project management and for data handling of the Sloan Digital Sky Survey, the most ambitious astronomical survey ever undertaken. During its five-year mission, the survey will create a detailed map of one-quarter of the entire sky, determining the positions and absolute brightnesses of more than 100 million celestial objects. It will also measure the distances to more than a million galaxies and quasars.

The SDSS with its Apache Point Observatory in New Mexico addresses fascinating, fundamental questions about the universe. With the survey, astrophysicists are mapping the large-scale patterns of galactic sheets, clusters, and voids in the universe. Different patterns of large-scale structure point to different ways the universe might have evolved.

The Sloan Digital Sky Survey has discovered the most distant quasars ever recorded. Studies of the image distortion due to the gravitational bending of light show that the unseen dark matter "halos" surrounding galaxies are about twice as large as previously believed. And still other data suggest that our Milky Way galaxy has cannibalized other galaxies: our galaxy's halo contains huge clumps of stars that appear to be the remains of

smaller galaxies assimilated by the Milky Way more than a billion years ago.

Tens of thousands of asteroids have been detected in the database, providing the statistical power to chart the distribution of asteroid families according to chemical composition and orbital types. Asteroid families are presumed to have originated in the same parent object, which allows evolutionary processes in the solar system to be investigated.

SDSS has generated 173 publications (103 in refereed journals), and 28 Ph.D. theses.



The Sloan Digital Sky Survey uses the Apache Point, New Mexico observatory for its effort to map the large-scale structure of one-fourth of the sky in three dimensions.

Pierre Auger: Probing the highest-energy cosmic rays

Fermilab is also project manager for the Pierre Auger Observatory, an international collaboration building an array of detectors to track and analyze high-energy cosmic rays that, though extremely rare, exhibit energy levels 100 million times higher than the Tevatron.

Physicists of the Pierre Auger project study the masses of ionizing radiation that are constantly striking the earth. Due to their high occurrence, low-energy cosmic rays have become relatively well understood in the 80 years since their discovery. However, cosmic rays at higher energies are much rarer and poorly studied.

There is no known acceleration mechanism for cosmic rays above energy levels of 1020 eV, and no recorded events point back to candidate sources. Possible conventional sources include radio loud galaxies, active galactic nuclei (AGNs), and neutron stars; possible exotic sources include super heavy dark matter, cosmic strings and monopoles.

In May 2001, the Pierre Auger Observatory's newly completed airfluorescence telescope observed its first cosmic ray air shower. In December 2001, the first particle detectors of an extensive surface array were in operation. In the early hours of 8 December, the fluorescence detector and the surface array recorded a single shower as it cascaded through the air and splashed into the array below. This shower, captured by two different but complementary techniques, was transmitted to collaborators around the world, demonstrating that the detectors, trigger, timing, data communications and data acquisition systems were working as designed.

The Engineering Array hybrid run was finished in March 2002. The observatory collected 70 hybrid events over a four-month run and is conducting analysis of these events.

The completed observatory will deploy 1,600 surface detector stations over 3,000 sq. km of desert in Argentina, with 24 fluorescence telescopes to overlook this array. The observatory needs such a large aperture to gather enough of the very-high-energy cosmic ray events to probe their origin. At such energies, cosmic ray particles are extremely rare. Above 10^{19} eV there is just one cosmic ray particle per square kilometer, per steradian, per year. Above 10^{20} eV there is only one per square kilometer, per steradian, per century.

The fluorescence telescope uses Schmidt optics, which, with their aperture stop and corrector lens, allow greater light collection and reduced coma aberration with a spherical mirror. This aperture is sealed with a window that is also an ultraviolet filter for selecting the nitrogen fluorescence lines. As a result, the camera, mirror and all of the electronics are contained in a clean, controlled environment.

The surface detector stations are 10,000-litre water Cherenkov detectors, each equipped with three 220 mm hemispherical photomultipliers. Each is self-contained, with its own data processing unit, radio transceiver and solar power system. Event triggers indicate the possibility that a large air shower has struck the array. These move by radio to the central data acquisition system, which examines them for interesting events.

The central data acquisition system is on the Auger campus, located at the edge of the array in the town of Malargu . The campus also contains the detector assembly building with

electronics shops, mechanical shops and a water purification plant. Besides the data acquisition system, the new Auger center building contains offices for staff and Auger collaborators, and a visitors' center.

In October 2001, an international review committee chaired by Werner Hoffman of the Max Planck Institute, Heidelberg, Germany, assembled at the Auger Observatory to evaluate progress. Its very favorable report was then received by the Auger Project Finance Board in Washington, which voted to proceed to completion. The collaboration hopes to finish the observatory by the end of 2004. Full construction has begun, but funding beyond 2002 is a concern.

CDMS: Searching for dark matter

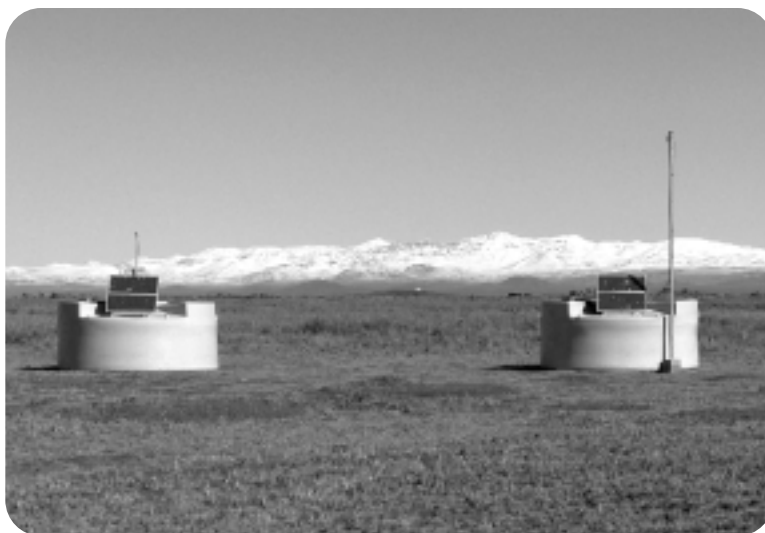
The Cryogenic Dark Matter Search (CDMS) is looking for dark matter in the form of Weakly Interacting Massive Particles, or WIMPS. These hypothetical particles could account for the invisible mass, observed indirectly by its influence on the formation and motion of galaxies and other heavenly objects. Assuming that WIMPS were in thermal equilibrium with the very early universe, one can calculate the abundance of these particles left in the universe today. If these particles are to provide the mass necessary to close the universe, their mass should be in the range 10 GeV to 10 TeV. (The proton mass is 1 GeV.)

The CDMS experiment aims at identifying WIMPS using a low background cryogenic detector. A large Germanium crystal is cooled down to about 20mK. A dark matter particle interacting with a nucleus in the crystal will produce both heat and ionization. The crystal is outfitted with NTD thermistors to measure the temperature elevation, and with charge collection pads. Signal redundancy is

used to reject background, which would produce a different heat/ionization ratio. A special low background cryostat (called Ice Box) has been designed to host the detectors.

The experiment's first stage is located at Stanford's Underground Facility. This shallow site has the advantage of being close to lab facilities, which will make improvements to the system easier. The second stage of the experiment is located at the Soudan mine in Minnesota.

CDMS has been taking data at Stanford for about 9 months with ZIP detectors developed for the Soudan Laboratory. At the Soudan, CDMS is commissioning the refrigerator at Soudan. The next step will be adding the data acquisition and the warm electronics to the system; these items are tested at Fermilab before being moved to Soudan. Finally, the tower of six detectors presently running at Stanford will be brought to Soudan for installation. Data taking could begin in autumn 2002.



A few of the 1,600 particle detectors used by the Pierre Auger Cosmic Ray Observatory, positioned in the thousand square mile expanse of the Pampa Amarilla desert at the foot of the Andes, in Argentina. The detectors will study air showers, to probe the origin of ultra-high-energy cosmic rays.

V. Computing: The indispensable tool

Fermilab could not achieve the high-energy physics frontier without cutting-edge computing capabilities. The Fermilab approach to Run II computing is serving as a prototype for computing at the LHC.

In Collider Run II of the Tevatron, Fermilab is meeting data acquisition and storage challenges that are unprecedented in high-energy physics. The 5,000 tons of tracking equipment housed in each of the collider detectors, CDF and DZero, are delivering on the order of 250 kilobytes of data per collision event and 20 megabytes of data per second, storing more than 200 terabytes of raw data a year and producing more than 100 terabytes of data for a year's worth of final physics analysis. (By comparison, it would take more than 10,000 PC's, each with a 30-megabyte hard drive, to handle 300 terabytes of data.) That rate is at least 20 times the data generated in Run I of the Tevatron, and with the total stored data will probably grow to at least 20 times the amount of Run I data.

The data acquisition, storage, and processing challenges rely critically on robust and highly performant network infrastructures, both on the Fermilab site and linking to outside institutions.

Fermilab's Computing Division provides round-the-clock computing facilities for data processing and analysis for Run II, and also for MINOS, MiniBooNE, remaining fixed-target experiment analyses, and new physics computations (such as accelerator simulations) as they arise. Fermilab also serves as the U.S. Tier 1 regional computing center for CMS, which will begin taking data at CERN later this decade.

A major focus for Computing over the next few years will be to provide the data processing and analysis systems for

Run II analysis. The many years of meeting Run II data taking and data processing needs will lead to increased reliance on all available collaboration computing—whether at Fermilab or the remote institutions—to achieve the physics results. Robust and high speed distribution of the data over the wide area networks has become an absolute necessity, given the numbers of scientists and institutions working all over the country and all around the world.

Fermilab is establishing a data sharing system with CERN for US CMS. Fermilab will become a Tier I Regional Center for storing and distributing data when the CMS experiment begins generating physics results from the LHC. The computing hub project has received both DOE and NSF support. Fermilab, the host laboratory for the U.S. collaboration building subassemblies of the CMS detector, is the collaboration's host laboratory for software, analysis and computing support. As host, Fermilab will have a continually updated copy of all the data used for analysis at CERN, and make it available to all scientists, at all universities and laboratories, in the U.S. collaboration of 35 institutions in 19 states.

From the Scientific Discovery Through Advanced Computing (SciDAC) program in the DOE Office of Science, Fermilab physicists and computer scientists are receiving approximately \$1.28 million a year for the next three years to participate in five nationwide collaborations: the Particle Physics DataGrid; Advanced Computing for 21st Century Accelerator Science and Technology; the National Computational Infrastructure for Lattice Gauge Theory, Storage Resource Management and Site Authentication and Authorization

These efforts share ambitious scientific goals: creating computer tools that will allow physicists to work at their home base with up-to-the-second experimental data from sources anywhere the world; and adapting those access tools to design the high-energy physics discovery machines of the future more efficiently and economically. As the major next step enabled by the SciDAC awards, the collaborations will help create a new generation of scientific simulation codes for “terascale” computers: computers capable of making trillions of operations per second (“teraflops”), while handling trillions of bytes of data (“terabytes”).

Lattice Gauge/QCD: Power off the shelf

The theory of quantum chromodynamics provides describes the evolution and properties of all quark systems. Equations in the full QCD theory use a four-dimensional lattice. To approximate a volume as large as a proton, a typical calculation requires a grid of 24x24x24 points. The fourth dimension, which tracks the evolution in time, might be cut in 48 slices, resulting in a 660,000-point lattice.

Precise lattice calculations are essential for measurements of the mixing of strange B and Bbar mesons, to illuminate the tiny difference in the behavior of matter and antimatter. Since autumn of 2001, Fermilab has gained the financial means for increasing computing power for lattice QCD. Introducing the Scientific Discovery through Advanced Computing program, the Department of Energy awarded Fermilab almost \$2 million over three years to develop a new supercomputer system. The SciDAC grant is part of a nation-wide effort to provide teraflop computing power for lattice theory projects in nuclear and high-energy physics, one of many SciDAC computing initiatives.

Collaborating with over 60 scientists from universities and national laboratories, Fermilab theorists are building a computer cluster consisting of 512 PCs, all off-the-shelf components. We will operate this computer cluster as a facility for the collaboration. Each node will have a processor capable of more than one gigaflop, and all nodes will be able to communicate with each other. Creating a teraflop machine (one million million floating point operations per second) for lattice theory requires both high-speed processors and high-speed communication.

In lattice QCD computations, communication among different nodes is a crucial element of the calculation, since all nodes need to share data on the quark fields. Each node is responsible for a subset of lattice points, and each node constantly exchanges information with neighbors. Superfast communication hardware is the key to creating the best lattice supercomputers.



The SGI commodity computers, which form part of a large cluster for parallel computing. Applications will include computer simulations of quark-quark interactions.

Advanced Computing for 21st Century Accelerators

The SciDAC accelerator modeling project is a national research and development effort whose primary objective is to establish a comprehensive terascale simulation environment needed to solve the most challenging problems in 21st century accelerator science and technology.

In June 2002, a SciDAC team announced the development of a new code for modeling colliding beams, with a collective set of capabilities making it unique among beam-beam simulation codes: it is parallel, it uses a slice model, it can model offset beams, and it can model collisions with a finite crossing angle. As an initial test, a simulation was performed to study the coherent beam-beam dipole oscillation in the LHC. The code will now be applied to modeling the Fermilab accelerator complex.

The code includes a new algorithm for solving Poisson's equation that is very efficient for modeling the long-range offset colliding beam situation. The team showed that it is possible to use a Green function approach without gridding the full region. The ability to accurately model and predict the performance of colliders is important to many accelerator projects, including the Tevatron, the PEP-II B-factory at SLAC, the Relativistic Heavy Ion Collider (RHIC), and the LHC.

U.S. Physics Grid Projects

The Particle Physics Data Grid is integrating and developing Grid-enabled tools for data-intensive requirements of particle and nuclear physics in collaboration with leading computer scientists in the field. Their goal is to bring Grid-enabled data manipulation and analysis capabilities to the desk of every physicist.

The GriPhyN (Grid Physics Network) collaboration is funded by the NSF. The team of experimental physicists and information technology (IT) researchers are investigating computational environments called Petascale Virtual Data Grids (PVDGs) to meet the data-intensive computational needs of the participating experiments

The International Virtual Data Grid Laboratory is an NSF funded collaboration that will enable Fermilab to work with the distributed TeraGrid and other initiatives together with U.S., European and Asian colleagues to achieve the CMS and other experiment data analysis goals.

The three U.S. Physics Grid projects are working closely with CERN and the European Grid projects to provide seamless distributed computing environments for the LHC experiments.

Challenges in data acquisition

In yet another area of computing advances, Fermilab hopes to contribute understanding to the issue of why things don't work as well as we'd like them to. The BTeV (B Physics at the Tevatron) experiment trigger will be challenged to reconstruct 15 million particle events per second, and to use that reconstruction data in deciding which events to keep for further analysis, while concurrently

finding and correcting errors. With a grant from NSF, the BTeV collaboration is building an advanced fault tolerant system into its trigger and data acquisition project. BTeV must assemble as many as 10,000 parallel computers and make them work together dependably and consistently in the triggering and DAQ system, despite incorporating different kinds of computers with different tasks.



Atipa representatives installed computer units in the racks at Feynman Computing Center. Computing administrators booted up the systems, one unit at a time, and began the 30-day "burn-in" with a suite of software tools designed to stress the various hardware components (CPU, memory, disk, network).

Major Program Initiatives



I. Making the Most of the Tevatron: Collider Run IIb

The prospect of a light Higgs boson intensifies the importance of Run II, for Fermilab and for the U.S. HEP program. With indirect experimental indications of a light mass for the Higgs boson holding firm, a successful Collider Run II at the energy frontier must remain Fermilab's highest priority.

The Tevatron collider resumed operation in March 2001 with the increased capabilities of the new Main Injector. The DZero and CDF detectors have been upgraded to operate at instantaneous luminosities of $2 \times 10^{32} \text{ cm}^{-2} \text{ sec}^{-1}$, an increase from the earlier run of over a factor of ten. The laboratory's goal for Run IIa is to deliver 2 fb^{-1} to each detector. This goal should be reached in several years of operation, at which time the capabilities of the detectors will begin to deteriorate due to radiation damage to the inner layers of silicon trackers.

Continued progress toward revolutionary new physics will require further increases in the collider luminosity, along with upgrades to the detectors to accommodate these increases. The lab has adopted what it regards as a realistic goal for this subsequent Run IIb of the collider: achieving an integrated luminosity of 15 fb^{-1} over the full Run II. Fermilab must develop the accelerator upgrades necessary for Run IIb to maximize the collider luminosity, before the LHC experiments begin running.

Run IIb detectors

The CDF and DZero collaborations have developed plans for replacing radiation-damaged silicon detectors with new detectors of simpler design with more rad-hard technology; and for upgrading data acquisition and triggers to deal with higher luminosity. Careful planning and implementation of the detector upgrades, and close coordination with accelerator upgrade projects, will be essential for success. The new detector components must be designed with the confidence that they will operate effectively throughout Run IIb, with anticipated integrated luminosity of at least 15 fb^{-1} . Installation of all detector upgrades must occur during a single shutdown of no more than six months' duration, with roll-out and roll-in tentatively scheduled in late 2005.

Run IIb accelerator complex

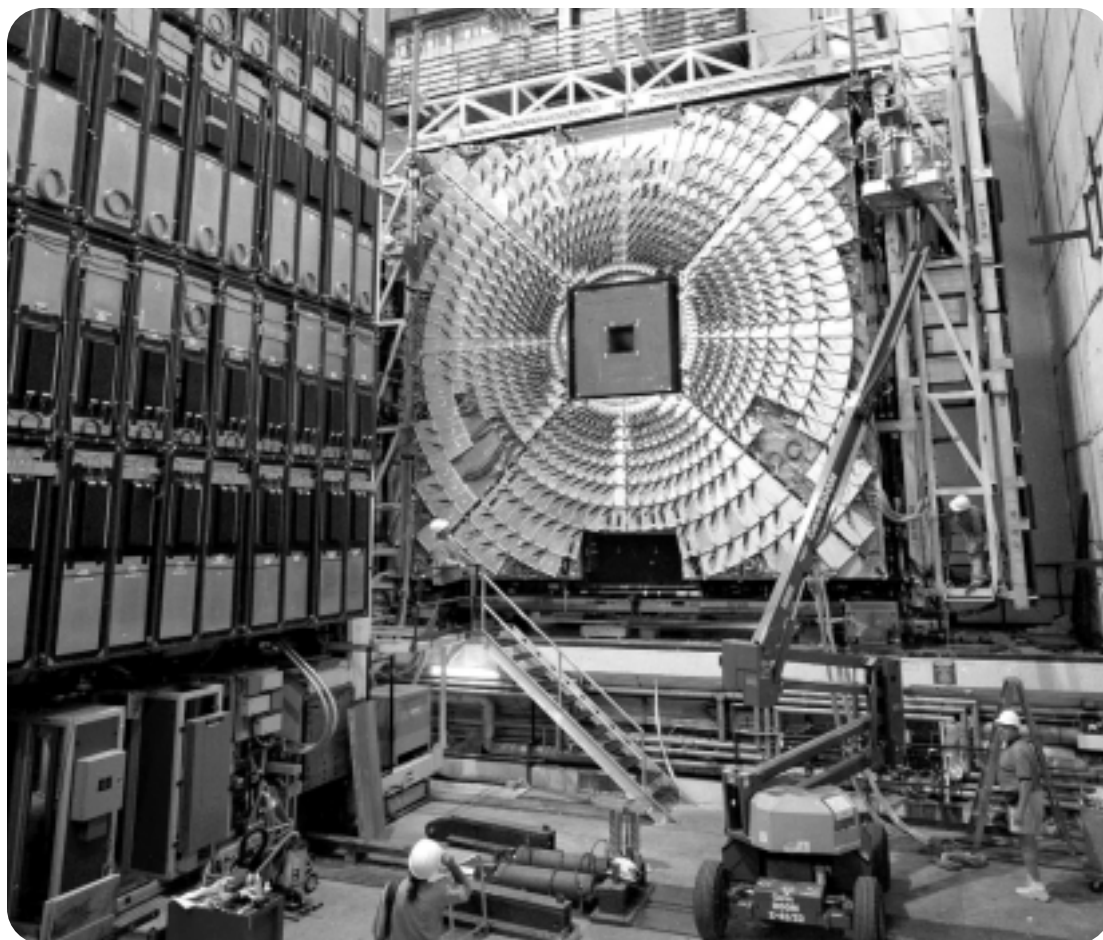
To exploit the unique physics window that is open before 2008, the Tevatron must deliver as many high-energy particle collisions as possible. The integrated luminosity goal of 15 fb^{-1} per experiment reaches into the region of revolutionary new physics. Any substantial increase beyond this goal significantly increases the physics discovery reach.

Fermilab must put a strong emphasis on achieving the highest achievable integrated luminosity during Run II. The Beams Division has developed ambitious plans and concepts for increasing Run II luminosity far above levels previously

attained. These include improvements in antiproton production, antiproton collection efficiency, and beam cooling in the Recycler, priorities.

Additional luminosity provided greater precision for electroweak measurements and greater reach for exotic searches, plus the opportunity to observe a low-mass Higgs boson. We must double or triple the luminosity with modest accelerator upgrades.

Currently, the lab must focus its attention on Run II. But every increment of integrated luminosity increases the likelihood of discoveries in Run II and Run IIb.



The 150-ton C-layer muon detection system is a critical component of the DZero detector. Individual detector elements are overlapped to form a continuous plate in a “fish scale” design (background center).

II. CP Violation in the B system, and Charged Kaons at the Main Injector

The Experiment to Measure Mixing, CP Violation and Rare Decays in Charm and Beauty Particle Decays at the Fermilab Collider (BTeV) is the ideal next-generation experiment on CP violation in quarks. With an innovative pixel-based trigger and precise electromagnetic calorimetry, BTeV will undertake a sensitive search for new physics by comparing CP asymmetries. BTeV will compile much larger samples in the critical B_d modes than the best current experiments, and larger samples than all experiments in the B_s modes.

With the addition of the Main Injector, the Fermilab Tevatron will produce more than 400 billion b-flavored hadrons per year and 10 times as many c-flavored hadrons per year. These heavy flavored hadrons will be an excellent resource for investigating CP violation, quark/anti-quark mixing and rare decays. BTeV is well positioned to answer the most crucial questions in heavy flavor physics.

Fermilab has been the historic leader in this area of physics since its 1977 discovery of the b quark, or upsilon particle. With BTeV, the lab has initiated an ambitious experimental program to extend the study of CP violation in the B system, using B and B_s mesons in a new detector at the CZero intersection region of the Tevatron Collider. The BTeV experiment has the potential to make the measurements that will not be completed by the programs currently underway. BTeV can be the definitive experiment that finally clarifies the picture of CP violation.

BTeV will be a central part of an excellent Fermilab physics program in the era of the LHC. The experiment's main goals are:

- tests of the Standard Model and searches for new physics through the precise measurement of CP asymmetries with B and B_s decay modes that have minimal theoretical uncertainty;
- measurement of rare B and B_s decays to search for effects of new physics;
- measurement of a broad range of B_s decays that become accessible with the particle identification and photon measurement capabilities of the BTeV detector.

We know much more about B_d meson decays than about the B_s meson, largely because of a long program of high-statistics B_d measurements, at the $\Upsilon(4S)$ and the Z resonances, at SLAC and CERN.

The origin of CP violation is one of the fundamental questions in high-energy physics. The BTeV experiment will exploit the enormous proton-antiproton cross section (100 mb) at the Tevatron, which yields 2×10^{11} proton-antiproton events per year. The existing Tevatron experiments, CDF and DZero, have significant capabilities for B physics, notably from silicon microstrip detectors and new, detached vertex triggers. But the BTeV detector is optimized for B physics rather than for the study of high- P_t events. It has sophisticated particle ID and photon-detection capabilities, as well as a pixel-based vertex detector/trigger system with pixels extending down to 6 mm from

the beam axis. It is designed to record 1 kHz of $b\text{-}\bar{b}$ events and 1 kHz of $c\text{-}\bar{c}$ events, with a 4 kHz total event rate.

Even with restructuring of the project, BTeV's capabilities should give it a significantly greater B physics reach than either CDF or DZero. To reduce costs, the detector is being built with one arm instead of two, and an interaction region magnet will be supplied from an existing experiment at the appropriate time, instead of being constructed separately. Precise measurements of rare flavor-changing neutral current processes and CP violation are and will be complementary to the Tevatron and LHC to unraveling the electroweak-breaking puzzle. Improvements in the detector, including an improved understanding of RICH detector's importance to muon and electron identification, will maintain a high level of physics sensitivities,

CKM and ultra-rare charged kaon decay

CKM (Charged Kaons at the Main-Injector) is an experiment to measure the branching ratio of the ultra-rare charged kaon decay $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ by observing a large sample of these decays (~ 100) with small background (< 10). The physics goal we obtain from this is a measurement of the magnitude of the Cabibbo, Kobayashi, Maskawa matrix element $|V_{td}|$ with a statistical precision of about 5%.

This measurement will play a critical role in testing the Standard Model hypothesis that the sole source of CP violation in nature resides in the imaginary parts of the V_{td} and V_{ub} Cabibbo, Kobayashi, Maskawa matrix elements. Attacking this question in the kaon sector is both experimentally and theoretically independent of the ongoing programs to measure these same parameters in the B meson sector. Each sector provides an independent test of the Standard Model description of CP violation. Both must measure the same parameters for that description to be correct. Such a parallel approach is critical to confirm, with confidence, both the Standard Model description of CP violation and the veracity of the individual measurements. The $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ decay mode is regarded as the theoretically cleanest system in which to measure the magnitude of V_{td} . The only important uncertainty in the relationship between the branching ratio and $|V_{td}|$ is a small contribution from the charmed quark which depends upon the poorly known charmed quark mass.

Evidence for this decay mode has recently been published by the stopped kaon decay experiment, E787 at Brookhaven National Laboratory (BNL). They reported the observation of two events with an expected background of 0.15 ± 0.05 events based upon the complete data set taken in 1995-8. They quote a branching ratio of $[1.57^{+1.75}_{-0.82}] \times 10^{-10}$ which is consistent with the current Standard Model prediction of $[0.75 \pm 0.29] \times 10^{-10}$.

The challenge of this measurement is truly experimental. We require the apparatus to control all backgrounds to less than the 10^{-11} level in branching ratio in order to reliably measure this kinematically unconstrained decay. To achieve a two-order-of-magnitude increase in sensitivity per year of data taking while maintaining excellent control of all backgrounds requires an apparatus with much higher rate capabilities than has been achieved in the BNL experiment. This has led us to a decay in flight experiment, in contrast to the stopped kaon technique used at BNL.

In addition to the paramount goal of measuring the $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ branching ratio we also plan a series of other measurements of rare charged kaon decay properties using the CKM apparatus. The high rate capabilities and redundant measurement capabilities of the CKM spectrometer will make it well suited to such a program of measurements.

A critical new feature of this experiment is a separated K^+ beam line based on super-conducting RF cavities operating in a transverse detecting mode at 3.9 GHz. This SCRF system is a major new development based upon the 1.3 GHz accelerating mode SCRF cavities developed at DESY for the TESLA project. A major effort is underway in the Fermilab Beams Division, in collaboration with the CKM experiment, to develop the cavities and associated beam line. The goal is a 70% pure debunched K^+ beam at 22 GeV/c with a flux of 50 MHz over the 1-second Main Injector slow spill.

We will use detectors that are well established in performance and reliability, and very high performance veto systems, with redundant measurements made for charged particles. There are high rate multi-wire proportional chambers to measure the incident kaon trajectory and vector momentum and low-mass straw tube chambers operating in the decay volume vacuum to measure the downstream charged pion trajectory and vector momentum. Redundantly, we will measure the vector velocity of the charged kaon and pion using very high rate velocity spectrometers based on phototube ring imaging Cherenkov detectors. The remainder of the detectors are a set of veto systems for photons muons and electrons. All of these vetoes will be scintillator sandwiched with lead or steel and readout with phototubes. Timing measurements with 1 ns precision will be made for all detector signals coming from the experiment.

CKM received first stage approval in July 2000. We have moved into a detector prototyping phase which will lead to a full technical design report. The first SCRF cavities have been fabricated and tested, achieving nearly twice the required field strength in the first 1-cell prototype. A muon veto prototype has been completed and tested at IHEP in Protvino. Prototypes of the upstream proportional chambers are under design and construction at the University of Virginia. A series of small prototypes for the straw tubes have been built at Fermilab leading to a prototype which will operate in a test beam while under vacuum. San Luis Potosi in Mexico has identified potential vendors for phototubes and accepted the first prototype mirrors for the RICH detectors. There is active work at Fermilab, BNL and IHEP on aspects and components of a prototype photon veto module. This prototype will be tested in an electron test beam with very high electron tagging efficiency to demonstrate the single photon inefficiency requirement.

III. Future Accelerator R&D: Creating and expanding options

In keeping with the January 2002 recommendations of the DOE/NSF High-Energy Physics Advisory Panel, Subpanel on Long Range Planning For U.S. High-Energy Physics, Fermilab has set a priority of becoming a credible host and construction partner for a linear collider. Fermilab is also expending effort in other areas to expand its options, and to continue to play a leading role in the U.S. contribution to any of the next-generation accelerators in any location.

Fermilab's overall accelerator R&D program has five elements:

- Linear Collider, with efforts in X-band and superconducting RF;
- Superconducting RF beyond a linear collider, including the Fermilab NICADD Photoinjector Laboratory (FNPL), Charged Kaons at the Main Injector (CKM), and High Brightness Photoinjector (HBPI);
- Superconducting magnets;
- Muon facilities;
- Proton driver.

In response to an environment of limited funding, the laboratory has been placing an increased priority on linear collider activities, with decreasing emphasis on muon facilities and low field superconducting magnet R&D.

Linear Collider

In a June 12, 2001 presentation to the DOE/NSF HEPAP subpanel, Fermilab Director Michael Witherell stated: "We propose to the U.S. and to the international HEP community that we work together to build a linear collider at or near the Fermilab site."

The directors of the U.S. laboratories have publicly stated their support for construction of a linear collider as an international endeavor based on optimum technology. This view is shared by HEPAP and by the corresponding European and Asian advisory panels.

Fermilab's goals for its efforts in the U.S. linear collider R&D program are to develop the technology supporting the construction of a linear collider with an initial center of mass energy of 500 GeV, a luminosity of at least $10^{34}\text{cm}^{-2}\text{sec}^{-1}$, and capable of being upgraded to an energy beyond 1 TeV.

The U.S. is in a unique position as the only region where the technology choice for a linear collider does not appear to be locked in. Furthermore, Fermilab is in a unique position as the only institution participating in both the NLC and TESLA collaborations.

The lab's strategy is two-fold: developing sufficient familiarity with both x-band and superconducting RF technologies to allow informed participation in the decision on linear collider technology; positioning Fermilab to play a leading role in the any international collaboration formed to construct a linear collider, whatever the technology chosen.

Fermilab's near-term goals are to complete R&D work on NLC leading up to a technology demonstration in 2004; to understand TESLA and contribute to the technology decision; and to understand the ramifications of building a linear collider at the laboratory.

NLC

The Next Linear Collider is an international collaborative project to design a high-energy, large-scale positron-electron collider.

The NLC is being designed principally by collaboration members in the United States and Japan. The U.S. leadership is centered at Stanford Linear Accelerator Center, and Fermilab is now a major U.S. partner. Leadership in Japan is concentrated at the Japanese Center for High Energy Accelerator Research Organization, located in Tsukuba.

The NLC collaboration is designing a 20-mile-long, 500 GeV linear collider, with upgrading possible to 1 TeV or 1.5 TeV to match physics needs as they evolve. The rf accelerating structures are designed by SLAC to work at the X-Band frequency of 11.424 GHz (11,424,000,000 cycles per second). Key areas and systems are designed for energies above 1 TeV. The main-linac rf systems are capable of generating 250-GeV beams (500-GeV cms collisions) in one half of the tunnel length that is included in the initial configuration. A main feature of the layout is a slight tilt (20 mrad) between the electron and positron main linacs that minimizes the bend angle needed to transport high-energy beams to one of the interaction regions, the high energy IR. The beam delivery system is sufficiently long to allow the high energy IR to be ultimately upgraded to energies in excess of 3 TeV.

Fermilab's primary responsibilities within the NLC collaboration include the development of a fabrication and industrialization methodology for NLC accelerating structures, structures fabrication for a test of the 8-Pack, and evaluation of potential sites in Northern Illinois.

TESLA

An international collaboration at the *Deutsches Elektronen-Synchrotron* (DESY) in Hamburg, Germany is developing the Tera Electron Volt Energy Superconducting Linear Accelerator (TESLA). Fermilab is one of five U.S. member institutions.

The TESLA concept extends to a total length 33 km, with two linear accelerators of 15 km each in tunnels approximately five meters in diameter. The collision energy is 500 GeV, using superconducting accelerating structures with an operating temperature of 2 Kelvins, or -271 degrees C.

Current Fermilab activities directly related to TESLA include modest continuing operational support of the TESLA Test Facility (TTF); an engineering-cost study of the TESLA proposal, which Fermilab led with Argonne, Cornell, DESY, Jefferson Lab and SLAC; flat-beam studies and Global Accelerator Network demonstration at FNPL, the Fermilab NICADD Photoinjector Laboratory; and identifying possible collaborations with and equipment contributions to TTF II.

In addition to the HEPAP recommendation, there appears to be a world consensus that the next goal for a forefront high-energy physics facility centers on the construction of an electron-positron linear collider. However, since construction of a linear collider is not assured, Fermilab's overall goals and strategy for a program in accelerator research and development are:

- To maintain strong research programs at the lab in magnets and radiofrequency, the enabling technologies of HEP;
- To establish capabilities that will allow Fermilab's participation as a leading partner in, and a credible host for, the construction and operation of the next forefront facilities for HEP;

- To preserve a variety of options for future initiatives in accelerator-based HEP;
- To advance knowledge in fundamental accelerator R&D, and partner with universities in training students.

Superconducting RF

A number of activities relating to both warm and cold superconducting RF are being carried out in concert, and Fermilab is expanding its efforts to draw the Technical Division into collaboration with the Beams Division in these areas.

Cold superconducting RF cavities are being developed to produce a separated kaon beam for E921, CKM (Charged Kaons at the Main Injector). CKM is a fixed target experiment at Fermilab designed to explore CP Violation by measuring the branching ratio of the rare charged kaon standard model decay $K^+ \rightarrow \pi^+ \nu \bar{\nu}$. CKM requires a pure K^+ beam, which will be produced using approximately 6 meters of cold superconducting RF cavities operating at 3.9 GHz in TM_{110} at 5 MV/m P_{TRANS} .

The Fermilab/NICADD Photoinjector Laboratory (FNPL) is exploring concepts for a high-brightness photoinjector facility at Fermilab. FNPL is operated jointly by Fermilab and the Northern Illinois Center for Accelerator and Detector Development. Participating institutions in FNPL are Fermilab, NIU, the University of Chicago, the University of Rochester, the University of California-Los Angeles, Lawrence Berkeley National Laboratory and DESY. There are currently two Ph.D. students researching at FNPL, in the areas of Flat-Beam Optimization (U. of Chicago) and Laser Acceleration (U. of Rochester).

The High Brightness Photoinjector represents the next-generation laser-driven electron source. It would give the

US a state-of-the-art facility for advanced accelerator R&D. The photoinjector would explore basic beam physics, support the new generation of Linear Colliders, Free Electron Lasers and synchrotron radiation sources, and serve as a training ground for accelerator physicists.

The lab has received an Expression of Interest (EOI) signed by three national laboratories (Fermilab, Argonne and Lawrence Berkeley) and seven universities (U. of Chicago, U. of Michigan, NIU, Northwestern, U. of Pennsylvania, U. of Rochester, UCLA) for construction of the High Brightness Photoinjector at Fermilab.

Superconducting magnets

Superconducting magnets are the enabling technology for high-energy hadron colliders. Fermilab is the U.S. center of excellence for superconducting magnet research and development, and intends to maintain that position.

The lab's goals are to develop superconducting magnet technology that could support a Very Large Hadron Collider in the post-LHC era, and to maintain the US leadership in superconducting magnets to benefit both Fermilab and the world-wide HEP program. The major components of the Fermilab program are LHC low-beta quadrupoles, and both Low-Field and High-Field dipole R&D. The high-field program and the LHC accelerator research program are likely to forge a strong connection in the near future and Fermilab intends to reinforce that connection. But as the result of severe financial pressures, the low-field program will be ending this year, with the completion of low-field magnet/power supply tests.

Muon facilities

Fermilab hopes to establish an R&D path to develop technologies required to support the initiation of construction of a neutrino facility based on a muon storage ring by the end of this decade. The lab would also like to explore options for interim facilities to support by R&D and programmatic goals. At Lab G, Fermilab is conducting R&D on high-gradient accelerating cavities

Fermilab also hopes to construct a MuCool Test Facility, at the end of the present 400 MeV Linac, to pursue the development of a muon ionization cooling channel for a high luminosity muon collider. Ionization cooling has been proposed as a method to intense beams of positive and negative muons. This technique involves passing the beam through an absorber in which the muons lose transverse- and longitudinal-momentum by ionization loss. The longitudinal momentum is then restored by re-acceleration, leaving a net loss of transverse momentum (transverse cooling). The process is repeated many times to achieve a large cooling factor.

A fully international collaboration (U.S.-Europe-Japan) has been formed to propose a cooling demonstration experiment. However, the program at Fermilab is under severe funding pressure, and its outlook is uncertain.

Proton Driver

Concepts are being developed for a new, very high intensity, proton facility that could represent an option for construction if a linear collider were not constructed at or near the Fermilab site in the coming decade. The “proton driver” would enable a number of research initiatives including, but not limited to, next generation neutrino experiments, rare kaon decays, neutron scattering, and ultimately support of a muon storage ring based “neutrino factory” and/or perhaps a free electron laser. Two schemes are being investigated, one based on a large aperture, rapid cycling synchrotron, the other on a superconducting linac. Both would provide 3×10^{14} protons/sec at 8 GeV (~400 KW), corresponding to close to 2 MW when accelerated to 120 GeV in the Main Injector.

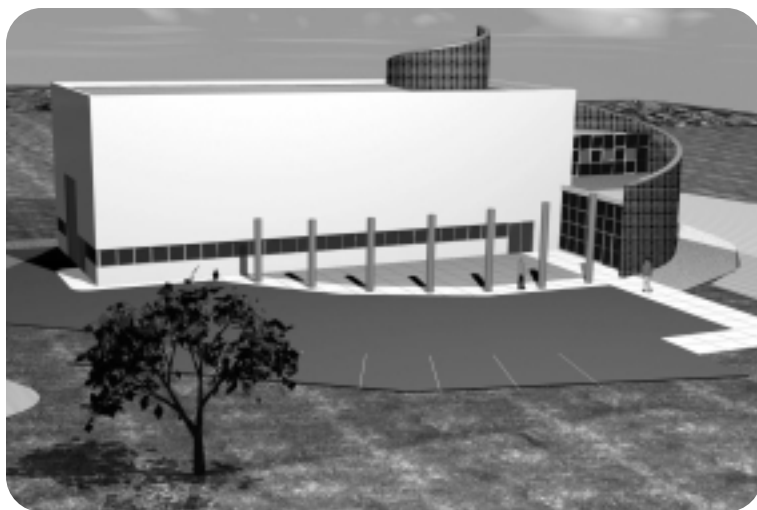
I. Environment, Safety and Health

Fermilab's emphasis on safety during the past five years has resulted in a remarkable reduction of employee injuries. In fact, the number of Lost Workday Cases in 2001 was the lowest in its entire history.

There is much work to be done, however, in achieving the same level of success among Fermilab's construction and service subcontractors. Efforts have been stepped up in recent months to inculcate the subcontractor workforce with the principles of Integrated Safety Management (ISM) that have proven so effective in influencing the behavior of Fermilab's employees. This effort, combined with some major changes in the contractual requirements of our newly awarded subcontracts is expected to result in future improved performance.

The NuMI construction project has presented a formidable safety challenge over the last couple of years. This \$30 million tunneling project required significant daily attention to be certain that the plethora of environmental and safety hazards were being adequately mitigated. As the civil construction of this project moves from the tunneling phase into the more conventional surface buildings and outfitting phase, it is expected that present levels of safety emphasis and oversight will continue.

With an eye toward reducing its environmental liabilities, Fermilab continues to invest a significant portion of its operating funds toward the cleanup and conversion of its onsite facilities. In 2001, two former target halls were stripped of their experimental apparatus and remaining radioactive and hazardous materials were removed. Major experimental components were salvaged for reuse elsewhere and most of the hazardous material (in the form of lead and beryllium) was recycled. Both of these facilities are now used for storing equipment, which has eliminated the need for offsite rental storage. Similarly, work continues in 2002 on the removal of one of the target piles in the Meson Building.



The MINOS service building, shown here in an architect's drawing, is prominently located near the Fermilab main entrance. It will continue the Robert Wilson legacy of unique and aesthetic architecture. A spiral, reminiscent of a particle track, relates the building's appearance to the research conducted inside. Construction of the building will begin in 2003.

Security Issues

Fermilab conducts no classified research. In response to the terrorist attacks of September 11, 2001, the lab took several precautionary measures to control access to its facilities. An additional six security personnel began patrolling the lab regularly. Laboratory employees were required to wear badges for the first time. Visitors were required to obtain passes when entering on laboratory business. Recreational use of the site was prohibited.

In attempting to balance the need for security with the laboratory's heritage of openness to the public, Fermilab continued to hold public events such as the Enrico Fermi Centennial Celebration and the Fermilab Arts and Lecture Series, and to allow access to the Leon Lederman Science Education Center. Additional restrictions were placed on parking locations for those attending the Arts Series events. In the ensuing months, Fermilab permitted access to walkers, joggers and bikers without requiring visitors' passes. In May 2002, the special Buffalo Viewing Pass was introduced, allowing visitors to drive areas adjacent to the buffalo pasture for viewing the herd that has stood at Fermilab since introduced by founding director Robert Rathbun Wilson in 1968. In June 2002, the lab introduced proximity card access to buildings regarded as sensitive areas not open to the public. Only employees and users with properly coded identification cards were able to enter these buildings.

With due diligence to security requirements, Fermilab maintains its commitment to welcoming the public to a 6,800-acre site offering many opportunities for recreation and the appreciation of nature.

ISSM

Fermilab embraces the principles of Integrated Safeguards and Security Management (ISSM), in the same way as it does Integrated Safety Management (ISM). By integration, we mean that security, like safety, is not treated separately, but is considered as we plan our work, conduct our work, and check our work after it is finished. Fermilab has used the same infrastructure for instituting ISSM as that used for carrying out ISM. Line management is responsible for security, just as it is for safety, and uses the existing safety or security support services for assistance in carrying out these responsibilities. The lab has integrated all ISSM steps requiring new action and is now in the "maintenance stage," looking for additional ways to strengthen security. DOE classifies Fermilab as "Property Protection Site." The lab has no classified material, no attractive nuclear material, and no proprietary data. Thus, our security responsibilities are much less intensive than those of other DOE sites.

Kerberos

To enhance computer security, Fermilab has adopted Kerberos, a system of “strong authentication” for computer users invented at the Massachusetts Institute of Technology, is already operating at many universities and several Department of Energy national laboratories. Fermilab introduced Kerberos for the CDF and DZero experiment collaboration computers during 2000, with a goal of extending the protection to the entire site.

Kerberos strives for the best balance between security and freedom by addressing the question of identity, and attempting to prevent identity theft. Kerberos establishes proof of identity (“user authentication”) through cryptographic calculations at local computers, with a central server validating the proof. Kerberos aims to keep passwords from being transferred

over networks, where they are vulnerable to “sniffers:” programs that watch for passwords going by, and harvest them for identity theft. Unfortunately, sniffers are everywhere.

Kerberos acts as a gatekeeper for access to certain high-priority services, while leaving lower priority services alone. There will be two access routes, via software or cryptocard. The first route involves installing software on a desktop computer so a user can prove a Kerberos identity locally. The desktop will exchange information with the Key Distribution Center, which issues a key or ticket good for a computer anywhere in the lab. The alternate route involves a cryptocard, which produces a one-time password. A user without a Kerberos identity will be given a cryptocard challenge, which, if passed, issues a one-time, one-use password.

The lab also has a “volunteer fire department,” the Fermilab Computer Incident Response Team. Volunteers from many areas of the lab take turns being on call to “put out fires,” providing the first line of defense against unauthorized access. Kerberos might not plug every hole, but has gained widespread acceptance through its adoption by vendors including Microsoft, Sun, Cisco, IBM and many others. In addition, the goal for the security system is to maintain openness and minimize disruptions in communicating scientific information.



Dennis McAuliff of Support Services identifies and tags individual PCs at Site 38. These are some of the more than 400 PCs in the lab's largest-ever single purchase of computers to boost physics analysis capability during the quest for new physics at Collider Run II of the Tevatron.

II. Communications and Trust

Office of Public Affairs: Reaching our neighbors, local and world-wide

In seeking to make friends of our neighbors and learn what's on their minds, Fermilab's Office of Public Affairs can now mine information from its first-ever community survey, funded and conducted in January 2001 by the Public Opinion Laboratory of Northern Illinois University.

From phone responses by 1,033 residents in surrounding communities, we learned that of those somewhat familiar with Fermilab, 90 percent trust the lab with regard to the environment and 81 percent feel the lab is open to feedback from the community. However, 53 percent were not overly familiar with lab and 22 percent would not buy a home near the lab. Yet it was encouraging to learn that 86 percent of those who never have seen Fermilab would like to make a visit.

Fermilab has always been a good place to visit. The Arts and Lectures Series annually draws about 11,000 patrons; the Education Office annually works with nearly 7,000 teachers, and more than 1,000 adults in tour groups. The annual Tornado Seminar in April draws an audience of about 2,500. Before the events of Sept. 11, 2001 led to restricted access, Public Affairs was the unofficial greeter for more than 30,000 visitors annually for self-guided tours and recreational purposes around the site. As a gauge of the level of interest in the lab and its environs, the last site-wide open house drew 15,000 visitors in 1997.

Maintaining access

While increased security concerns have led to curtailments of the lab's historically open nature, Fermilab and the Department of Energy have worked closely together to find ways of maintaining public access without compromising security. The lab and DOE quickly understood that closing the site greatly affected relationships with the neighboring communities: concerns were voiced that the lab might be a dangerous place to be under any circumstances, and recreational users accustomed to site access over the years (bikers, birders, joggers, etc.) were extremely frustrated by the change. But the Arts and Lectures Series remained open, offering a major demonstration that visitors could be admitted under precise stipulations. With gradual measures, the site was opened to visitors to the Lederman Science Education Center, to visitors with passes, to visitors for recreational use who walked or biked onto the site, and most recently to visitors with special buffalo passes, who were allowed to drive on the site to view the herd of American bison that has symbolized Fermilab's presence on the frontier of high-energy physics since 1969.

In planning for a future that reinforces this public welcome, the Office of Public Affairs has embarked upon a project to make a Fermilab visit a unique experience with a coherent appearance and message. In May 2001, Public Affairs formed a Design Task Force with representation from various areas of the lab. A prototype exhibit, "PULSE: Accelerator Science in Medicine," was mounted in the Wilson Hall Atrium to celebrate the 25th anniversary of the

Neutron Therapy Facility on Sept. 8, 2001. The task force is also formulating an overall plan to provide a coherent framework for the visitor experience throughout the site, and its pilot project is a new exhibit for the 15th floor of Wilson Hall. The key messages will include science as a pathway of discovery, scientists as real people, physics without borders, the advance of technology, and accessibility of a national science laboratory to the nation's citizens—and to other nations' citizens.

It's also important for Public Affairs to visit the laboratory's neighbors and maintain contact in all possible ways. Representatives attend community meetings and offer presentations where and when appropriate—for example, at the DuKane Valley Council, the East-West Corporate Corridor Association, Chicago Wilderness, and various homeowners' associations. The Speakers' Bureau turns down no requests, annually averaging appearances with 20 adult groups and 20 school groups separately from the many school visits of the Education Office. Public Affairs has a policy of never missing a phone call, viewing each call as an opportunity to make a friend for the lab. The Fermilab Web site, administered by Public Affairs, includes a community forum (www.fnal.gov/pub/about/community) featuring questions from neighbors and responses, and links to areas of concern such as safety and the environment.

Major effort: NuMI

Neutrinos at the Main Injector (NuMI), the \$170 million project to send a beam of neutrinos from Fermilab to the Soudan Mine in northeastern Minnesota, 450 miles away, has required the excavation of 4,000 feet of tunnel and the construction of two large underground experiment halls on the lab site. NuMI is the first project of its kind at the lab; previous tunnels have used cut-and-cover methods. The NuMI excavation required blasting and the use of a tunnel-boring machine.

When the \$30 million excavation contract was awarded in 1999, Public Affairs began preparations with the experiment for a strategy of public interaction. Limits were placed in the contract on noise levels and weekend activities. A community relations plan included regular warnings on noise and vibrations. Before the first blasts occurred in May 2001, Public Affairs and experiment representatives attended several neighborhood meetings, and made presentations at meetings of the Kane County Board and the Batavia City Council. Local police and fire departments were informed, flyers were distributed in adjacent neighborhoods, and press releases were issued.

Once blasting began, Public Affairs continued communications with neighbors through flyers, letters, a mini-open house, tours exclusively for neighbors, and prompt, thorough response to any complaining phone calls. There were about 50 phone calls during construction, usually in clusters. Maintaining a careful logbook of the blasts helped separate legitimate concerns from unrelated complaints. An independent company (Vibratech), which had monitored conditions on the site since the outset of blasting, began recording noise and vibration levels in

neighboring communities in December 2000. Vibrattech representatives spoke directly with 16 neighbors who complained of noise and vibration.

Outreach efforts were frustrated by miscommunication and by schedule delays. Initially, blasting was to last only four months, but continued with schedule delays for 24 months. Blasting occurred on weekends, contrary to agreement, and sound levels were higher than anticipated. Some creative solutions were necessary, such as installing new blinds on the bedroom windows of neighbors who complained that a spotlight on the site shone directly into their bedroom, disturbing their sleep. Vibrattech followed up on complaints of cracked walls and broken windows, which were not the results of blasting; Vibrattech's records and data frequently demonstrated that complaints of house vibration following blasting noise were not possible, since ground vibrations travel 12-18 times faster than the sound and arrive three-to-four seconds before the sound arrives. Public Affairs was challenged to maintain good neighbor relations with ongoing news coverage of such issues as the project failing to receive re-baselining in a DOE review, and an accident that forced a temporary shutdown of the project.

Though the project has remained behind schedule, the safety record has improved, the blasts have been completed, and complaints have been diminished. The project also received re-baselining from a DOE review in August 2001. The NuMI outreach effort could serve as object lesson and case study for a possible large construction project on a future machine, perhaps a linear collider as recommended by the DOE/NSF High-Energy Physics Advisory Panel.

Community Advisory Group

Fermilab is negotiating with NIU and the Illinois Consortium on Accelerator Research to fund the establishment and implementation of a community advisory group, which would "represent a spectrum of views, to consider issues related to Fermilab's future as it affects both the lab and the community, and to provide advice to Fermilab's management." We hope to begin this effort in the fall of 2002.

FERMINEWS

Fermilab's distinctive physics newsmagazine, with a circulation of nearly 15,000, aims to support the lab's science mission, carry messages to DOE, offer a credible response to bad news, build morale within the lab, reinforce national and international connections, and direct the message of the importance of basic science research repeatedly toward readers who are prepared to hear that message.

FERMINEWS regularly includes policy stories, enterprise science stories of lab developments, targeted stories for issues of morale and support, explanations of scientific principles ("Physics Made Painless"), coverage of the lab's environmental and educational efforts, and portraits of scientists as people. The publication has always enjoyed the strong backing of lab management, and of the scientists themselves, who appreciate the opportunity to talk about their work. *FERMINEWS* delivers the message of HEP with credibility, and is highly regarded throughout the field. *FERMINEWS* also won a 2002 Gold Trumpet Award, for "distinguished achievement in planning, creativity and execution of a public relations effort," by the Publicity Club of Chicago, the nation's largest independent public relations membership organization.

As a strategic audience, *FERMINEWS* identifies state and local officials, DOE, OMB, OSTP, NSF, Members of Congress, Congressional staffers, science journalists worldwide and URA university presidents. As an informational audience, *FERMINEWS* identifies employees, retirees, users, vendors, physicists worldwide; university physics departments, libraries and labs worldwide, physics buffs, students and teachers, and neighbors. Representative readers include Joseph Blatt, a producer for NOVA (who wanted to make sure his subscription continued at a new address); Jared Cohoon, President of Carnegie Mellon University (who wrote good naturedly to correct a misspelling of "Mellon"); Suhail Yusuf of Karachi, Pakistan (who wrote, "I pray to Allah for your success and all the members of Fermilab"), and Congressman Vern Ehlers of Michigan (who, during a visit in 1999, remarked to lab director Michael Witherell, "so I read in *FERMINEWS* that you hope to build a new accelerator out there").

FERMINEWS continues its evolution as a U.S. HEP, not just of Fermilab. Public Affairs is actively seeking the cooperation of other labs in communicating the message of high-energy physics. The recommendations of an April 2002 DOE Peer Review of the Office of Public Affairs included the establishment of national newsmagazine for U.S. HEP, in conjunction with SLAC and with the cooperation of other national labs conducting HEP research. Public Affairs hopes to launch this national HEP newsmagazine in June 2003.

Some of the most prominent voices in national science policy have stressed the importance of science communication.

Vern Ehlers, in the 1998 report "Unlocking Our Future: Toward a New National Science Policy," wrote: "Research sponsored by the Federal government should be more readily

available to the general public, both to inform them and to demonstrate that they are getting value for the money the government spends on research. Agencies that support scientific research have an obligation to explain that research to the public in a clear and concise way."

John Marburger, Director of OSTP and Science Advisor to the President, declared at the AAAS Symposium on Science and Technology Policy (April 11, 2002): "We cannot fund all the sciences, all the time, to the full extent that we'd like. Choices need to be made. We need to advise the government on how to evaluate and make those choices wisely, and not leave them to random decisions of the public finance process."

FERMINEWS accepts that responsibility.

New Web efforts

The Office of Public Affairs, working with an outside contractor, launched a new Fermilab Web site on March 1, 2001 to coincide with start of Collider Run II of the Tevatron. The Web offers a unique communication tool with a controlled message, and the lab has far more visits electronically than in person. The Web is a resource for the media, for funding agencies and for the public.

The overhaul of the site took nearly a year. The new presentation won praise from both sides of the spectrum. The site was described by *"wired.com"* as "Euro-cute." The National Institute of Standards and Technology select the site for a presentation at the conference, "Communication the Future: Best Practices for Communication of Science and Technology to the Public," in March 2002 at Gaithersburg, Maryland.

Since the launch of the new site, Web visits have increased from 38,000 to more than 55,000 per week. Public Affairs works to build traffic by keeping

the site fresh and up-to-date, including a newsbox updated daily; and by keeping the site easy to navigate by an audience extending from physicists, to students, to neighbors, to Members of Congress, to vendors, to reporters, to DOE and other federal agencies, and to birders (the page devoted to the birds of Fermilab is one of the more popular destinations).

Continuing to advance the site's currency, Public Affairs has initiated regular updates on the status of the Tevatron and the beam luminosity, an accelerator update on all components of the accelerator complex, live events from the DZero and CDF colliders, and video streaming by Visual Media Services of presentations at the lab. Extending the reach of the Ask-a-Scientist program, Public Affairs had established a Virtual Ask-a-Scientist program, a monthly two-hour discussion with Fermilab scientists on-line.

Public Affairs is continually revisiting the question of how to make the Web site the most effective community outreach tool, and how to use it to improved internal communication. *FERMINEWS* is being coordinated even more closely with the Web site. And greater collaboration is in store with other HEP institutions in establishing a new site, "interactions.org," as well as setting up a worldwide image bank for high-energy physics labs.

Education: Teaching teachers and reaching young minds

Fermilab's Education Office is a local, regional and national resource for teachers seeking to improve science education. The staff of Fermilab's Education Office (established in 1989) and the Leon Lederman Science Education Center (celebrating its 10th anniversary) train and work with six to seven thousand teachers every year, as part of the mission to improve the way science is taught in surrounding communities and across the nation. Through its many programs, the Education Office extends the reach of the idea of science education as an interactive process.

QuarkNet brings high school students and teachers to the frontier of 21st century research that seeks to resolve mysteries about the structure of matter and the fundamental forces of nature. QuarkNet centers are connected to HEP more than eight HEP experiments including CDF and DZero at Fermilab and ATLAS and CMS at CERN. There are 44 QuarkNet centers already operational, with a goal of 60. Teachers join research teams with physicists at a local university or laboratory. Their students have an opportunity to learn fundamental physics by participating in inquiry-oriented investigations and analyzing live on-line data.

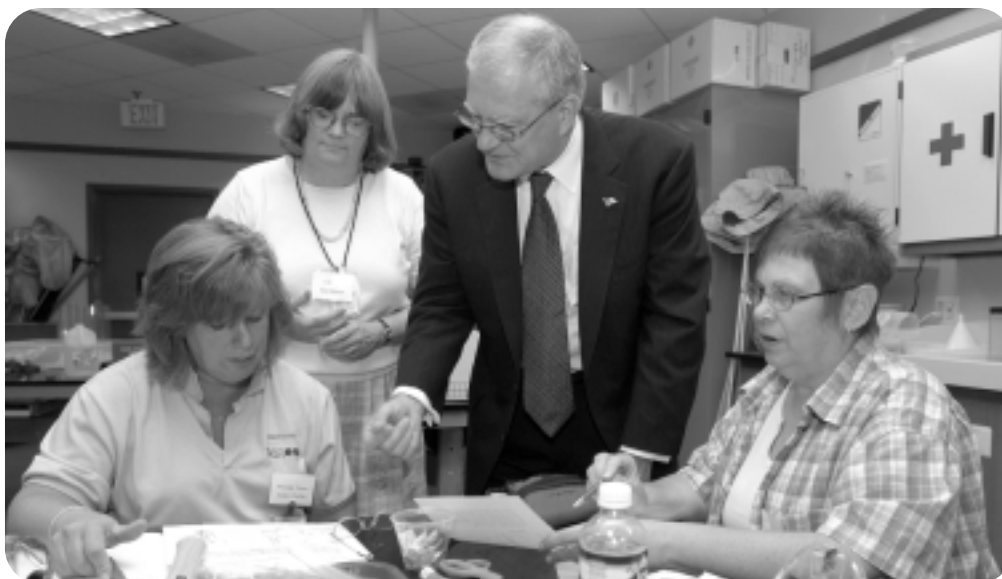
The Teacher Resource Center provides a preview collection of K-12 instructional materials and acts as a resource and clearinghouse of science, mathematics and technology education ideas. Educators have access to curriculum materials, books, multimedia, educational supply catalogs, periodicals and newsletters. The collection also includes reports on science and mathematics education, standards, assessment, equity and other topics. TRC services include

outreach resource and Internet awareness workshops, consultation assistance (available on request), and telephone reference. A US Department of Education Eisenhower National Clearinghouse Demonstration Site for the North Central Region is located in the TRC.

In addition to program listings and schedules, the Education Office Website hosts a wealth of resources for students and educators. Among the Web-based instructional materials are classroom projects that incorporate the best uses of technology. The projects, written by classroom teachers, are collaborative, student-driven and technologically dependent. When skillfully applied, technology can enhance learning in new and powerful ways. Other projects rely on student-analysis of Fermilab physics data. Three projects bring the prairie to life accessing databases in flora and fauna, images of the prairie, and slides from the "Particles and Prairies" videodisc. Fermilabyrinth, is a collection of Web-based games developed from selected hands-on exhibits at the Lederman Science Center.

The Education Office offers Science Adventure classes, which cover a variety of science and mathematics topics for K-8 students and workshops for K-12 teachers. Teachers who complete the workshops may bring their students to Fermilab for a field trip. These popular field trips allow students to be apprentice scientists conducting field studies in the prairie or give them a chance to see how physicists study the subatomic world at Fermilab.

The Education Office could not offer the range of programs currently available without the help of the Fermilab Friends for Science Education, which seeks to create and support innovative science education programs. FFSE fulfills its mission by enhancing the quality of precollege science education in public and private schools; encouraging young people to pursue careers in science and engineering; and promoting a broader public awareness and understanding of science.



Office of Science and Technology Policy Director John Marburger and Marge Bardeen (standing, left), head of Fermilab's Education Office, confer with local teachers undergoing training at the Leon Lederman Science Education Center.

III. Management Practices

Human Capital: The most important resource

Excellence in science is achieved by creating and maintaining an environment that enables all employees to contribute their full potential toward the Laboratory's mission, values and goals. We continue striving to increase and enhance our diversity representation through hiring, development and retention efforts.

The Laboratory promotes career opportunities and enriches the diversity of its applicant pool by attending job fairs and career days at colleges and universities serving populations historically underrepresented in the sciences. The summary below represents specific activities that we have attended and will continue to support as financial and human resources permit.

Recruiting

Fermilab has participated in both graduating student on-campus recruiting as well as Cooperative Student Job Fairs. Fermilab went to University of Illinois Urbana-Champaign and University of Michigan in March of 2001, for engineering recruitment. We went to Northern Illinois University in February for a Cooperative Student Job Fair and again to the University of Illinois Urban-Champaign in March of 2002. Other job fairs we've attended include Brass Ring Chicago; MLK Classic Diversity Fair at Illinois Institute of Technology; Shomex Co., sponsored with the NAACP

The Laboratory has also advertised employment opportunities in the following:

- HACE – Hispanic Alliance for Career Enhancement
- *Diversity Careers*
- *Workforce Diversity*
- *Minority Engineer*
- *Woman Engineer*
- SWE – *Society of Women Engineers Journal* (Magazine and Conference Guide)
- Equal Opportunity Publications
- National Society of Black Engineers
- SHPE – Society of Hispanic Professional Engineers
- *Winds of Change*
- IEEE Spectrum – Institute of Electrical and Electronics Engineers
- *Graduating Engineer*
- *Careers and the Disabled*
- *Chicago Tribune*
- Local area Newspapers
- ChiefMonster.com
- *Chronicle of Higher Education*
- *Physics Today*
- *CERN Courier*
- SHRM – Society of Human Resource Management
- IT Careers
- Cass Communications (variety of college town daily papers)
- *Nature*

The Laboratory continues its membership in the Prairie View A&M University cluster. This initiative will increase our visibility at this campus, a URA associate member, and will provide us with enhanced opportunities to recruit for interns and regular full time employees. The Laboratory is also represented on the Minority Engineering Advisory Board, College of Engineering, University of Illinois at Chicago. The Laboratory will continue its collaboration with the Illinois Department of Rehabilitation (DORS) to identify FNAL positions where persons with disabilities may be bridged into employment.

The Laboratory provides pre-college, college, and graduate opportunities to increase the numbers of historically underrepresented minority students selecting science and engineering as careers.

TARGET is a program for academically talented minority high school students. Annually since 1980, the Laboratory offers a 6-week combined work and enriched classroom experience to 25 participants, chosen from Chicago area schools and programs.

The Laboratory is a prime sponsor of the program "Tomorrow's Scientists, Technicians, and Managers" organized through the Urban League affiliate in our area. Students from this program are also recruited for TARGET.

The Laboratory is a member of the "Youth Motivation Program" through the Chicago Area Chamber of Commerce. To support this initiative, Laboratory employees volunteer their time to speak at Career Day at local high schools.

Each year, since 1970, the Laboratory has invited approximately 20 college minority students to the Laboratory to participate in a 12-week program, Summer Internships in Science and

Technology (SIST). Students must be matriculating in Computer Science, Electrical or Mechanical Engineering, or Physics. They are recruited nationally and from Puerto Rico.

Graduate Degrees for Minorities in Engineering (GEM). This program provides tuition. Since 1978, the Laboratory has been a member of the National Consortium for and stipends for students seeking advanced degrees in engineering and the sciences. The Laboratory is currently supporting 5 fellows.

The Lab provides mentoring and financial support for minority students working toward a Ph.D. in Physics at an URA University. The program currently has 2 fellows (1 Hispanic female and 1 African-American female). The program has had 6 graduates.

The Equal Opportunity Manager serves on the Minority Engineering Advisory Board at the University of Illinois at Chicago. This group works to develop strategies to assist African-American and Hispanic engineering undergraduates in their preparation for professional placement upon graduation. Each year Fermilab provides speakers for two courses, Engineering 189 and 190, and Engineering Corporate Day at UIC; for the past three years we have participated in "Shadow as Engineer Day", designed to help freshmen students strengthen their commitment to Engineering as a career.

The Laboratory has a Co-operative Education Program (CO-OP) that provides students with a combination of work and school experience. In FY 2001, we participated with seven universities and provided employment and training opportunities for 15 students.

Development

The Laboratory continuously updates its training modules addressing diversity awareness. A discussion and video on managing diversity is incorporated in the 12-week Supervisory Development series. Additional training is provided throughout the Laboratory on sexual harassment prevention and disability awareness.

The Laboratory has initiated three training programs to further develop the skills of its supervisory personnel. The first of these is "Accelerating Leadership in the new Millennium", designed for upper management. "The Effective Manager" is designed for middle managers. "Positive Employee Relations" focused on recognizing factors contributing to a negative work environment and pro-active measures to minimize these obstacles. These classes will continue in FY 2002. Starting in 2002 single classes will be offered to help supervisors and employees enhance their skills in a particular area, for example, conflict resolution, team management, time management. The Laboratory is also exploring the use of computer-based training.

The Laboratory has a tuition reimbursement program, which is available to all full time employees. In order to be eligible for Fermilab's tuition reimbursement, the course work or degree program must be job-related to the person's current job or one to which he/she can reasonably aspire. The Laboratory has a very unique aspect to this program called tuition advancement. The Laboratory will advance the cost of the course(s) for employees not on probation (the advance must be repaid if the person does not satisfactorily complete the course). This aspect of the program has proven to be a real assistance to those employees who would like to upgrade their present job skills without having the financial burden of paying for the course upon enrollment.

For FY 2001, a total of 111 employees participated. (% of labs total population) Of this number there were 16 minorities (4.4% of the Laboratory's minority population) and 33 females (7.1% of the Laboratory's female population). These employees attended 28 universities and colleges.

Retention

The Laboratory offers programs that are family-friendly, and has won recognition in the form of the Golden Family Award from the Chicago regional chapter of the Society of Women Engineers, citing the lab for "outstanding support of family issues." The award has also been won by such noted companies as Motorola and Lucent Technologies.

The Laboratory has had on-site day care, The Children's Center, since 1980, and is fully staffed to handle children age's 6 weeks through 6 years. A family leave policy and flexible spending tax-exempt accounts for dependent care have been established. The Laboratory offers Day Camp in the summer for school age children, featuring swimming, crafts, day-trips, and other activities. Wellness Committee programs have been offered focusing on family issues such as elder care, financial management, gender specific health issues, and estate planning.

The Laboratory offers problem resolution programs. The Laboratory has continued Management Training designed to provide supervisors and managers with an updated skill set in leadership techniques and practices and in understanding the complexities of managing people, teams, and projects. The Laboratory has a well-established and promulgated Grievance Procedure to provide employees a formal process to discuss workplace problems and resolutions with management.

Additionally the Equal Opportunity Office provides an avenue for internal complaint resolution. The Employee Assistance Program Counselor is also available to help arrive at resolutions to individual workplace and personal problems.

All Division and Section Heads are responsible for the implementation of the Affirmative Action Program within their specific areas. Additionally, semi-annually, the Director reviews our goal achievement and progress. Issues pertinent to our AAP goals and initiatives are presented at the Laboratory Administration Management meeting on a continuing basis throughout the year.



Wilson Hall, Fermilab's headquarters building, was inspired by the design of a Gothic cathedral in Beauvais, France.

Site, Facilities and Infrastructure Management

Introduction.

The information contained in this section for Fermi Lab's site, facilities and infrastructure is derived from the DOE facilities information management systems (FIMs) and the Fermilab Strategic Facilities Plan (SFP). As part of the Institutional Plan this information is intended to identify infrastructure asset management requirements and actions necessary to ensure that Fermi National Accelerator Laboratory continues as an efficient and effective world-class scientific research facility well into the 21st Century. These include:

- **Mission.** Facilities will be right-sized to the type and quality of space and equipment needed to meet mission needs and includes co-location of activities, minimization of leased space and adaptability to changing research requirements.

- **Working Environment.** Creation of a "preferred" working environment to attract and retain high quality staff and users to include the latest advances in information technology.

- **Environment, Safety, Health and Security.** To satisfy all necessary ES&H and Security elements for workers, visitors and neighbors.

- **Operations and Maintenance.** Infrastructure including facilities and other systems such as roads, utilities and equipment will be funded, operated and maintained from a life-cycle asset management standpoint.

Description of Laboratory Site and Facilities

Site Characterization

The Fermilab site contains 6800 acres of land and has 337 buildings totaling 2,232,691 square feet of space. In addition to this space, Fermilab has 112 trailers that provide additional space of 84,839 square feet in support of laboratory operations

Utility systems.

Fermilab utility systems include electrical, natural gas, pond water systems (industrial cooling water), potable water (domestic), and sanitary (wastewater).

ELECTRICAL

■ Description.

Electric power for the Fermilab Main Site is provided by Commonwealth Edison Company from their 345 kV transmission lines and over 26000 MW of electrical generation and supply contracts for Northern Illinois. Transmission line 11120 is the preferred line between the Electric Junction and Lombard Substations with Line 11119 between the Electric Junction and Wayne Substations serving as the second source of transmission to the site. Between Fermilab owned and operated high voltage substations, Kautz Road and Master Substation, the 345 KV bus is transformed through seven (7) 40 MVA and one (1) 60 MVA transformers to 13.8 KV for underground distribution through 22 feeder breakers. Fermilab secondary distribution consists of approximately 280 substations with from 15 miles of overhead conductors and 100 miles of underground cable. In addition, 34.5 KV lines from Electric Junction serve the Village 12.4 KV overhead distribution system and provide emergency 13.8 KV from the Village and Giese Road.

■ Current Condition (reliability)

The current condition of Fermilab electrical power system is adequate. The new components installed under the main injector project and selected feeders upgraded within the last few years are rated as good. Other secondary systems including transformers and conductors, as well as some primary 13.8kv feeders have elements that are rated as poor based on their current condition. As critical systems are identified as vulnerable or as failures have occurred, those sections have been replaced.

POND WATER SYSTEMS

■ Description.

Fermilab provides its own Industrial Cooling Water (ICW) from site sources and when needed is able to draw make-up water from the Fox River under a State of Illinois permit. The Industrial Cooling Water system at Fermilab has a dual purpose. It is used to supply water to the various fire hydrants and fire protection sprinkler systems located in buildings across the site. In addition, ICW is utilized in many of the experimental areas as a source for conventional magnet cooling. The distribution system for ICW extends from the main pumping station at Casey's Pond to the Support Area, Wilson Hall and Footprint Area, and most of the Experimental Areas located on the Fermilab site.

The main storage reservoir for the ICW system is Casey's Pond which is located in the northern portion of the Fermilab site.

There are two sources that provide water to the reservoir. A site-wide network of lakes and ditches is used to collect runoff water, as well as heat exchanger and sump discharge water, and return it to the main reservoir at Casey's Pond.

Water is also collected in the Main Ring Lake, located within the main accelerator ring, and Lake Law, located in the southeast portion of the site. The water from these lakes is then transferred to the main reservoir by means of a pumping station located at the Main Ring Lake. It is important to note that the entire Fermilab 6,800 acre site provides runoff to this network of ditches and lakes and thus even open areas of the site contribute to the experimental effort of the Laboratory. There is a second source used to supply water to the main reservoir. The State of Illinois allows Fermilab, when water levels are sufficient, to pump water from the nearby Fox River to supplement and maintain capacity at the main reservoir.

■ Current Condition (reliability)

The current condition of the Fermilab Industrial Cooling Water (Pond water) system is adequate. The main reservoir has been expanded in the last few years for increased capacity and gas fired turbines provide a dual fuel source for a well maintained pumping system that is rated as good. The site has about 105,000 linear feet of piping for this non-potable water distribution system some of which is nearing the end of its useful life. The most critical sections with the highest vulnerability to fail have been identified and have either been replaced or are planned for replacement. The ditch return systems and pond water control systems are in need of repair more from a water conservation standpoint but are satisfying the current capacity needs.

NATURAL GAS

■ Description.

From two separate metered source points, gas is delivered to Fermilab by NICOR and purchased under a supply contract with the Defense Energy Supply Center. The primary gas supply is an 8-inch line metered at the Wilson Road boundary. Two branch lines extend south. One serves the Village while the other terminates at the Central Utility Building. A second 4-inch back-up supply line has been recently completed which supplies gas through a meter station at the west boundary of the site, adjacent to Giese Road. This line is connected to the Central Utility Building gas supply. Through a system of sectioning valves, limited gas supply can be maintained to the site in the event of an interruption of the 8-inch primary supply. The pressure site-wide is regulated to maintain 100 psi. The Village and Site 38 are regulated to maintain 60 psi. Natural gas is primarily used for heating; however, it is also used to drive turbine engines for generating emergency electricity at Casey's Pond, Well #3, the Master Substation, and Wilson Hall. The site has approximately 65,000 lineal feet of underground natural gas piping owned by the federal government and maintained by Fermilab. Fermilab currently consumes around 100,000 Deka-therms (MMBTU) per year which equates to one hundred million cubic feet of gas supply.

■ Current Condition (reliability)

The current condition of the Fermilab gas system is good.

POTABLE WATER

■ Description.

There are three main and seven minor domestic water supplies that provide domestic water to the various areas of the Fermilab site. The Main Site system supplies domestic water through a piping network to the majority of the facilities on site. The primary water source for this system is Well No. 1 located near the Central Utility Building. Water is pumped from the well into a 50,000 gallon reservoir adjacent to the plant. There it is chlorinated and then pumped through the site-wide distribution system. The secondary source for this system is Well No. 3 located north of Road B and east of Receiving Road. When Well No. 1 is not in use, water is pumped from Well No. 3 into a 50,000 gallon reservoir at that well site. The main site water system is owned and operated by Fermilab.

Domestic water is supplied to the Village Residential Area and the Village Technical Area by a direct metered connection to the community water supply of the neighboring Village of Warrenville. This system, also Fermilab owned and operated, is a separate distribution system independent of the main site distribution. In addition to potable water, this system provides the source of water for the fire protection systems located in the Village Areas.

The third public water supply at Fermilab is the water supply located at DZero. This system supplies water to the Colliding Beams Experimental Facility at DZero. The water is pumped from nearby Well W-5 and is chlorinated at DZero prior to distribution. The DZero site will soon be connected to the main site domestic water supply once the new utility corridor currently under construction is completed.

Seven additional shallow water wells serve individual buildings at outlying sites. These are wells associated with the farm sites that existed when the land was originally acquired by the Atomic Energy

Commission. They are kept in service to supply water to the adjacent, former farm residences and storage buildings which are still utilized for various laboratory requirements.

■ Current Condition (reliability)

The current condition of the Fermilab potable water system is adequate. The water wells are well maintained and in excellent condition. The distribution systems are in need of repair.

SANITARY SEWER

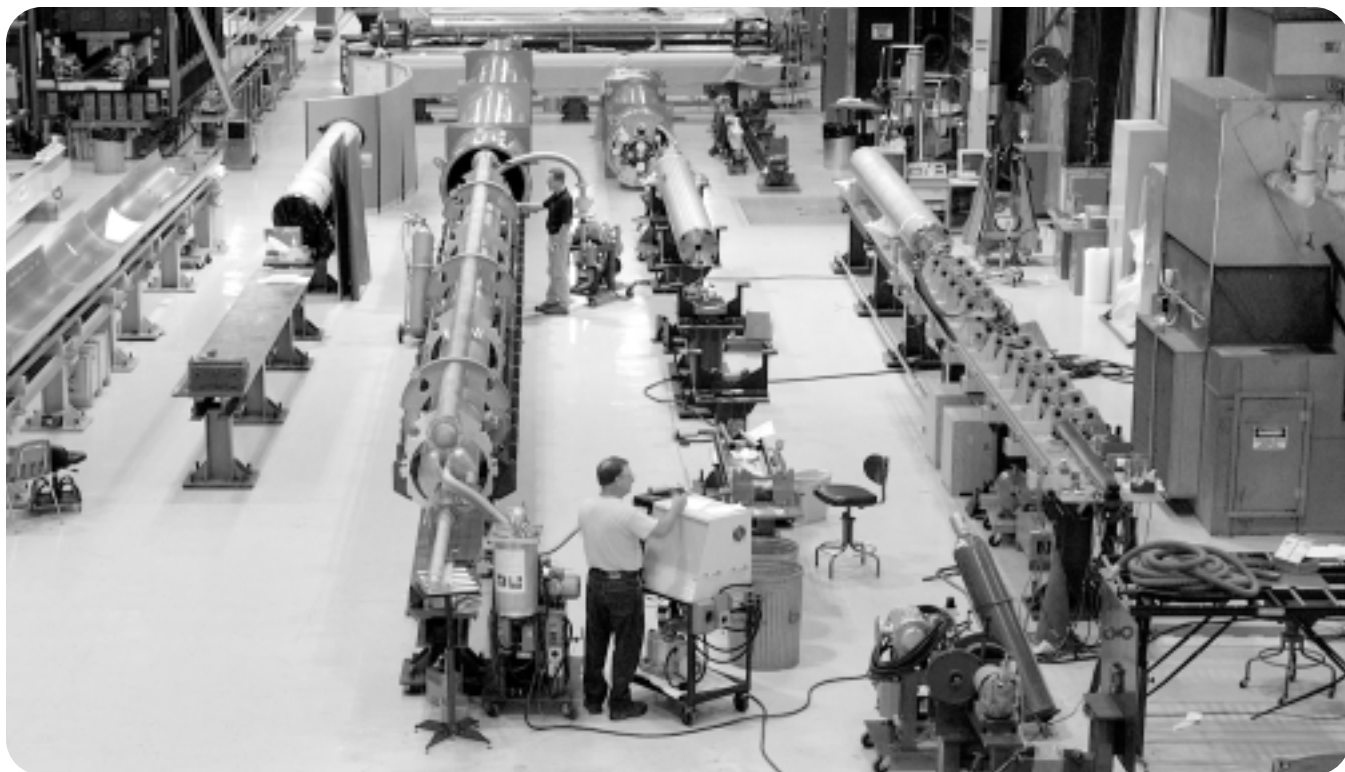
■ Description.

There are two (2) underground sewage collection systems at the Laboratory. One serves the main site, and the other serves the Village area. The main site collection system has six (6) lift stations; the Village system has one. No sewage is treated on site. Sewage from the main site is delivered and treated on a fee basis by the City of Batavia. Sewage from the Village is handled by the City of Warrenville under a similar arrangement. Fermilab owns and operates the sanitary collection system. The sewage system at the site contains 37,000 linear feet of gravity feed sewage line, 12,000 feet of pressure fed sewage line, and septic tanks with a capacity of 14,000 gal.

■ Current Condition (reliability)

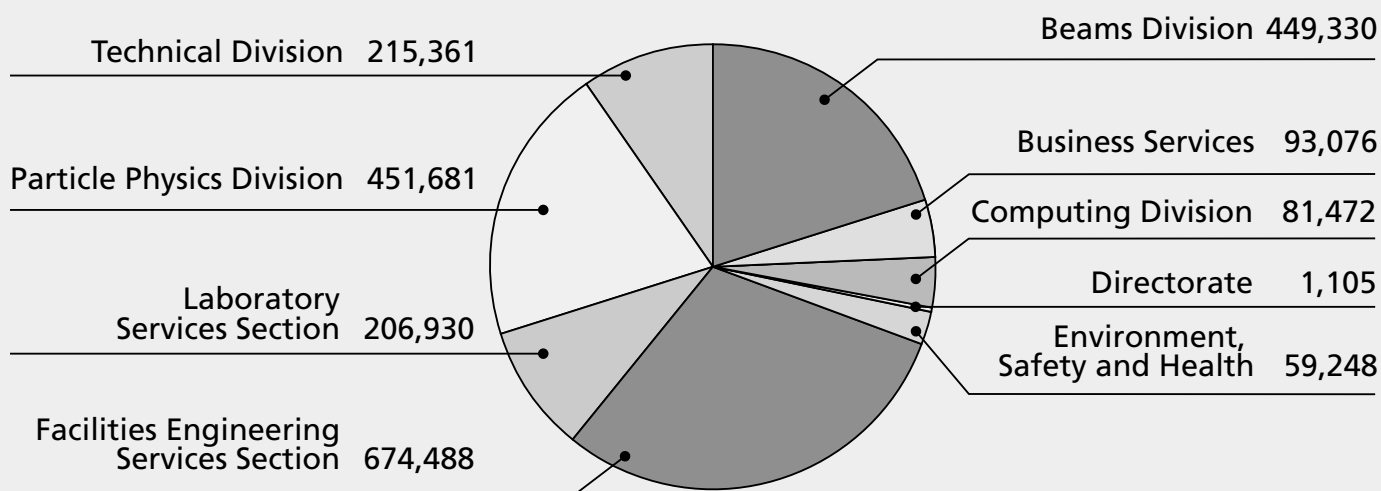
The collection system serving the main site facilities is in good working condition. A recent inflow and infiltration study has been completed that identified necessary repairs and improvements to this system to increase operating efficiencies and improve the capacity of the collection system. Off site collection of Fermilab's wastewater by the City of Batavia is marginally adequate and being jointly studied to determine alternate solutions.

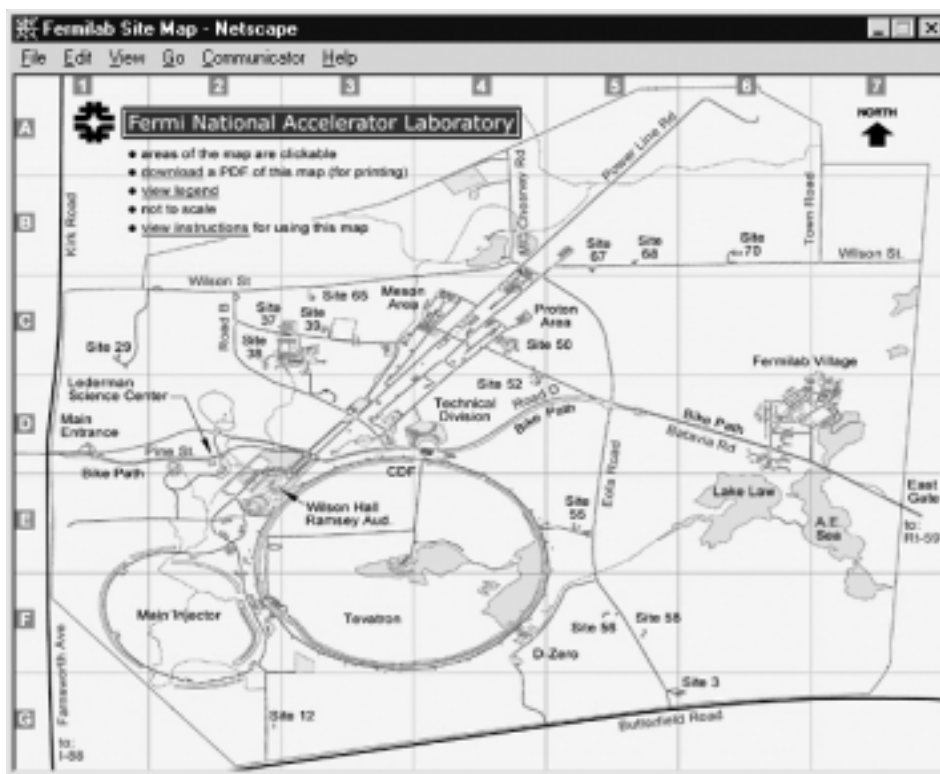
Infiltration has been substantially decreased in the Village system due to recent repairs, 40% of the Village system has been replaced.



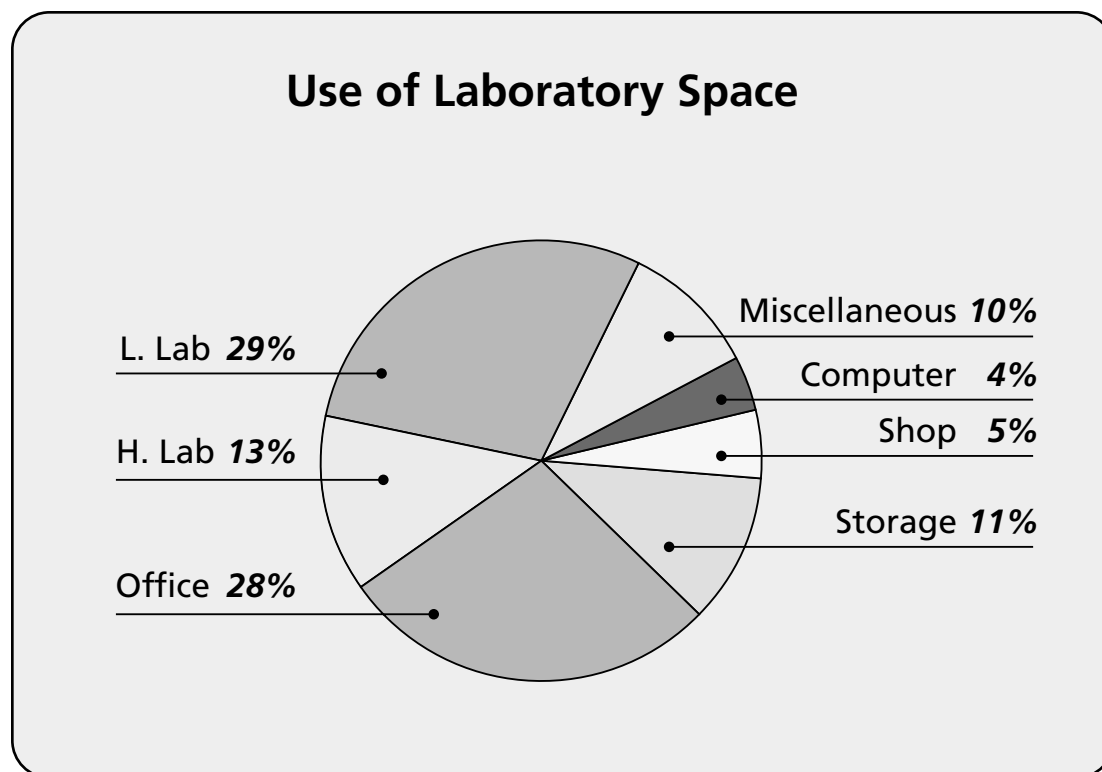
The magnet test area at Fermilab with the first quadrupole-corrector magnet assembly, consisting of two Fermilab quadrupoles and a CERN correction coil. Denny Gaw (foreground) and Jan Szal perform a leak check before the assembly is inserted into its cryostat vessel.

Laboratory Space Utilization by Division and Section





The Fermilab website interactive map provides an overall view of the site with a “zoom-in” function for high-traffic and high-concentration areas. The interactive map is one of many new features added since the introduction of the new website design.



Replacement Plant Value (RPV)

The RPV for Fermilab infrastructure is listed at \$1.423B and is subdivided into Buildings at \$367M and Other Structures and Facilities (OSFs) at \$1056M. Fermilab further subdivides the OSFs into Accelerators at \$963M and Other OSFs at \$93M which includes primarily the utility systems described. The breaking out of Accelerators is necessary since these figures should not be figured into the recapitalization period (time necessary to rebuild the lab with current annual investment of GPP and line item funding). The justification for this is that Accelerators including tunnels and equipment would not likely be recapitalized but rather replaced by other more state of the art machines.

Replacement Plant Value (RPV)	
Buildings	\$367 Million
Accelerators	\$963 Million
Other Structures and Facilities (OSFs)	\$93 Million
Total	\$1.423 Billion



The Feynman Computing Center, headquarters of Fermilab's Computing Division.

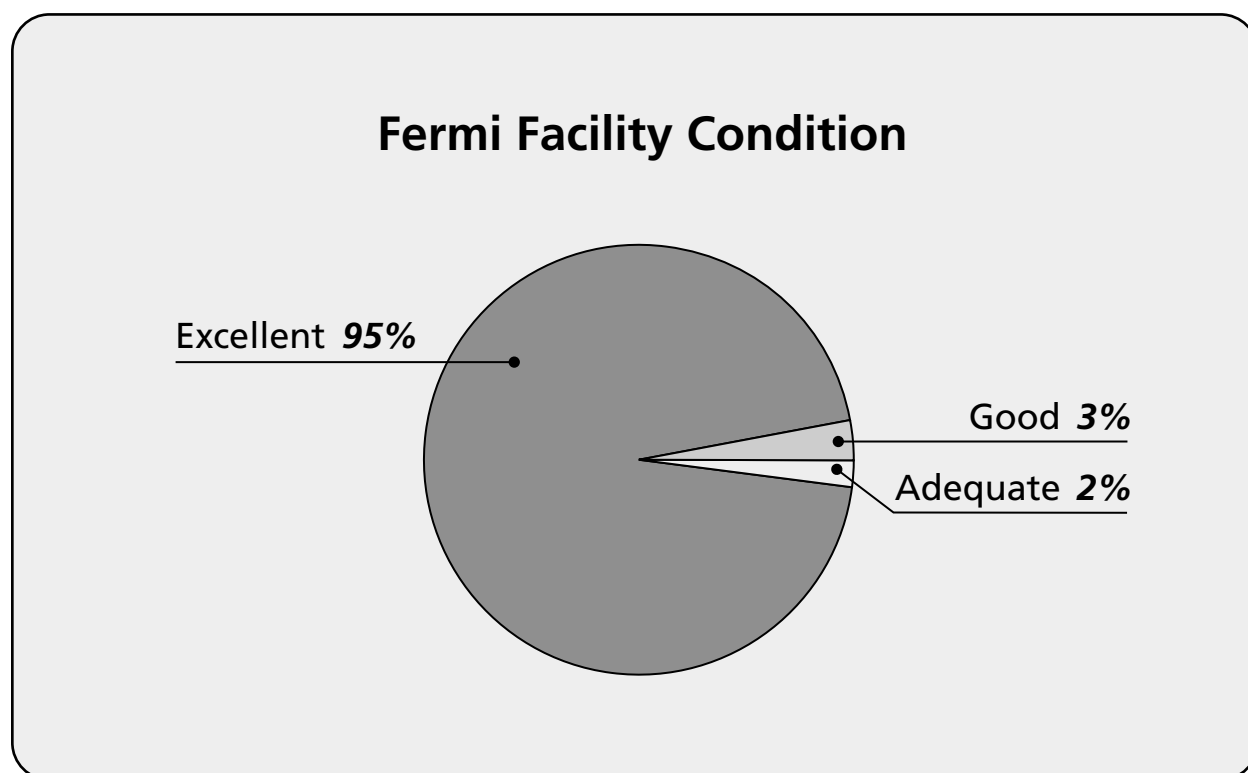
Condition Assessment Surveys

Condition Assessment Surveys are basically building and utility system deficiency inspections to assess the condition of the facilities. This is an important piece of Infrastructure management in order to identify funding needs and ties directly into the lab's maintenance planning and budget forecasting. Standardization of the process is being considered by DOE across all laboratories, but for now the current building assessment process at Fermilab is as follows:

1. Triennial Inspections for building envelopes and systems
2. Coordination pre and post inspection with Landlord
3. Written report with recommended prioritization
4. Meeting with Landlord to finalize prioritization
5. Estimates completed on high priority deficiencies
6. Projects proposed for landlord budget process
7. Entry into Facility Information Management System:
Required, Actual and Deferred maintenance fields
8. Close contact with landlord on progress

■ **Facility Condition Index (FCI)** – reflects the maintenance backlog. It is calculated as Total Deferred Maintenance as a percentage of Replacement Plant Value (RPV) where Deferred Maintenance is maintenance that was planned but not performed. The FCI underestimates true condition because it does not include major rehabilitation/renovations and improvements needed to better accommodate mission activities (e.g. improvements in vibration, air quality, temperature, access to power, etc.). Deferred maintenance/ replacement value is the FCI and is used as an indicator of facility condition.

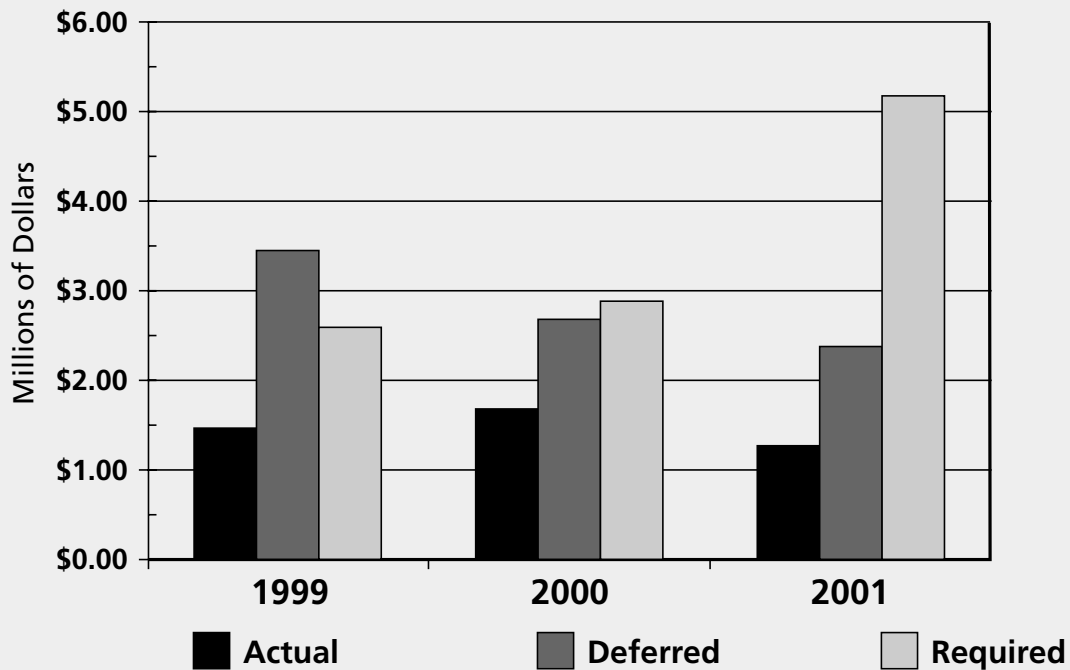
Facility Condition Index (FCI)	
319 buildings – Excellent	< 2%
8 buildings – Good	2% < 5%
6 buildings – adequate	5% < 10%
2 buildings – fair	10% < 25%
1 building – poor	25% < 60%
1 building – fail	≥ 60%



■ **Real Property Maintenance—**

Actual maintenance is the actual cost of all real property maintenance activities in the current fiscal year. Required maintenance is the estimate of all costs to perform maintenance activities deemed necessary by engineering and life-cycle studies. Deferred maintenance is maintenance that was planned but was postponed to a future period due to lack of funds.

Maintenance at Fermilab / Buildings Only

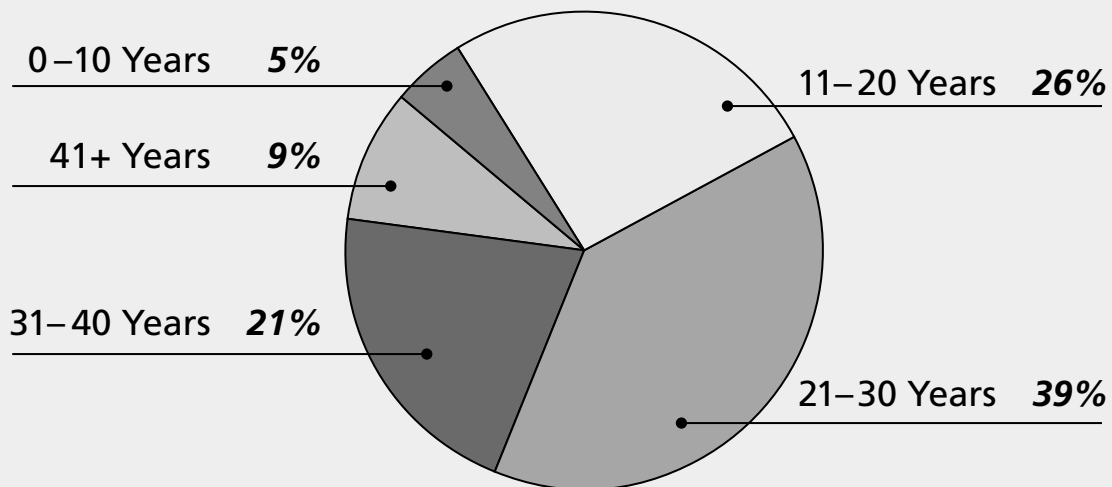


Age of Facilities

The distribution of age for the buildings is shown in the following graph. The buildings less than 30 years old were constructed specifically for laboratory operations while the buildings over 30 years old were predominantly part of the original land acquisition for the site and included a residential village complete with utility systems.

Age of Space	
Age (years)	Building Area (KSF)
<10	143.57
11-20	569.442
21-30	1153.606
31-40	123.754
>40	210.075
Total	2200.447

Age of Building Space at Fermilab (Years)



Laboratory Site and Facilities Trends

Resource Needs Summary

To satisfy the requirements identified in Section VI, Plan for Modernization (including Collaborative Research projects, Integrated Workplace projects) and existing and projected Infrastructure projects, Fermilab has identified the funding requirements over the 10 year period of this plan (2004-2013) in the areas of GPP and operating funds as described and included in the spreadsheet included herein. Appendix A identifies projects for the Utility categories.

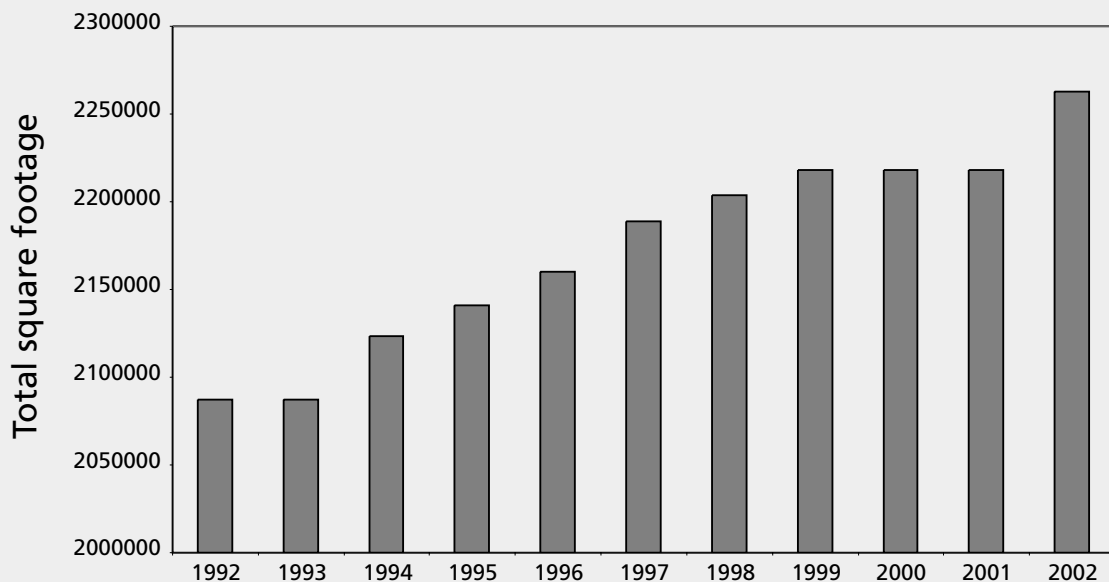
A. Line item funding

Fermilab currently has no line item projects. However, the ongoing site wide master planning efforts are expected to generate line item candidate projects not currently covered by this plan. The order of magnitude is shown in the chart below.

B. General Plant Projects (GPP)

With the exception of some of the projects under \$100,000 (identified in Appendix A) that will be funded from Real Property Maintenance funds, all projects requirements are proposed for GPP funding. Through GPP funding and continued third party investment, all requirements can potentially be satisfied.

Laboratory Site and Facilities Trends



Master Planning potential (Line item)	Cost (\$Millions)
Particle Physics Division	5-8
Technical Division	8-13
Computing Division	3-5
Integrated Workplace potential	Cost (\$Millions)
Smart Laboratory	1-3
Utility Category	Cost (\$Millions)
High voltage structures	2.8
High voltage feeders (13.8 kV)	6.1
Cooling water upgrades	3.6
Village domestic water upgrades	0.6
Sanitary sewer upgrades	2.2
Master substation upgrades	3.2
Main site domestic water wells	2.7
ICW water and distribution	4.8
Natural gas system upgrades	2.6
CUB system upgrades	4.2
Pond water system upgrades	3.6
<i>Total</i>	<i>36.4</i>
Other Categories	Cost (\$Millions)
Building roofing systems	4.4
Roads and trails	2.9
Building improvements	18.8
<i>Total</i>	<i>26.1</i>
Grand Total	62.5

C. Real Property Maintenance

Funding for this infrastructure element includes annual real property maintenance and repairs including structures and utilities, roofing, chiller/boiler replacement, and other mechanical, electrical and lighting, including preventative maintenance, cyclical maintenance, and service calls.

Funding for Real Property Maintenance based on FY02 budgeted maintenance is at 1.34% of the replacement value of Fermilab's non-programmatic

infrastructure (buildings and utilities with an RPV of \$460M). The SC guidance for the FY2000 Strategic Facilities Plan stated that sites should trend towards 1.5% by 2010. This is based on the Federal Facilities Council recommendation of 1.5%. Fermilab is expected to achieve the 1.5% in FY04 as shown in Appendix A (Resource needs). Recent discussion on increasing this level to 3% is believed to be more of an investment level that should include GPP and UIP type funding and further discussion on the RPV denominator will be necessary.

Summary of 10 Year Infrastructure Plans (updated SFP for FY2004-2013)

Trends and types of projects for modernization.

The changing nature of research cited in the SFP guidance considers collaborative research, technology evolution, technology zoning and integrated work place concepts. Through the planning process, Fermilab concluded that technology evolution and zoning as described in the guidance has taken place at Fermilab to the extent necessary to conduct the type of research planned and projected in the foreseeable future. However, collaborative research and integrated work place guidance facilitated further development of several key initiatives at Fermilab.

1. Collaborative Research. One concept and associated projects that offer modernization advantages to accommodate the advancements in science and the way modern research is conducted is the Fermi Technology Campus master plan.

The existing Lab A - Lab G complex was constructed in the mid-1970's as a research area for fixed target neutrino experiments. Associated modest support functions, including machine shops, technical shops and offices were included from the beginning. After the original experiments in the facilities were concluded, additional rounds of experiments were done with the Tevatron fixed target beams. As the Tevatron Fixed Target program wound to a close in 1997-1999, Fermilab management recognized the need for a master plan

for the area which set the long term vision of the area. In 1998, this master plan, termed the Fermi Technology Campus, identified and documented this vision. The plan provides for a systematic conversion and adaptive re-use of the existing buildings and infrastructure for the detector research, design and construction uses currently envisioned to support physics research. Since detector improvements in the field of high energy physics are constantly changing, each new and renovated space is being designed for maximum flexibility in order to accommodate new as-yet-unknown uses.

It was recognized early in the developmental stages of the plan that the implementation would be funding driven and driven by real programmatic needs. In other words the "master plan" was to serve as a guide for development of the area. Several projects (Lab C-D Connection, parking revisions) have already been designed and constructed in accordance with the master plan to fill the Particle Physics Division's need for space associated with a Silicon Detector assembly area. The next phase (Lab A-B Connection) has been designed and will be used to move technical facilities out of Wilson Hall, thereby allowing scientists to utilize Wilson Hall for collaborative interactions between experimental groups.

Consolidating operations where applicable

Technical Division Industrial Building 5.

Technical Division, within Fermilab, is responsible for the development of superconducting magnets, the key component of the accelerator. It took several decades for the Technical Division to develop its magnet technology to the present level. The current Technical Division was originally organized as the Technical Support Section in 1983. At this time the Technical Services (consisting of the Conventional Magnet Facility and the Machine Shop) and the Energy Saver Section (consisting of the Superconducting Magnet Facility and the Magnet Test Facility) were combined to create the Technical Support Section. In the mid 1990s the Technical Support Section became the "Technical Division." Although research was a part of the work as a Section, the change to become a full-fledged Division made R&D a major portion of the mission of the organization. Consolidation of older facilities with facilities required for new mission has been started through funding of a Master Plan for Technical Division that will likely result in the new facility for the reasons described in the next column:

- Alleviate the space/safety problems associated with Lab 4 (Something needs to be done to fix the known problems).

- Provide room for expansion to accommodate high precision machines in a controlled environment.

- Allow for a consolidation of activities.

- **Incorporate the Wilson Hall and IB4 shops. (This frees up valuable space in both buildings and allows consolidation of supervisor activities).**

- Provide the capacity to absorb additional satellite shops (as required).

- Locate the main shop in a more convenient and centralized site. (Should allow a better coordination of machine shop operations and also result in cost savings just due to transit time to and from the shops).

The existing machine shop facilities in the village are among the oldest at the Laboratory that require high maintenance.

Eliminating excess buildings

Fermilab's excess facility program is relatively new and in development as part of the sitewide master planning initiative. Fermilab initiated this effort through submission of projects in support of the Particle Physics Divisions Master Planning. It should be noted that of the near two million dollars in project requests, a majority of this request was to remove obsolete beamline enclosures. This request when funded will remove 19,605 SF from the Fermilab inventory. As part of the lab's Master Planning process, Fermilab will be investigating space consolidation and additional excessing actions to support the newly established requirement commencing in FY03 for offsetting demolition square footage for each new construction project that adds building space. The Fermilab excess facility project demolition submittals are shown below:

Project title	FIMS number	Demolition costs
Neon Compressor building - funded	625	\$ 53,000 (FY02)
Muon Beam enclosures (22)	701030125	\$ 1,151,000
Muon Beam enclosures (pilot-3)	701030125	\$ 178,000
Lab G trailer	T-060	\$ 31,000
Bubble Chamber equip. removal	602 (equip.)	\$ 233,000
PCenter trailer	T-009	\$ 18,000
Laser Building	602 (annex)	\$ 67,000
Lab G concrete slab	NA	\$ 70,000
Shed B Site 50	945	\$ 26,000

Employing cost efficiencies

An Integrated Workplace (SMART Lab) feasibility study was recently completed under a DOE FEMP direct funded project that supports the SMART Lab master plan concept currently being developed at Fermilab. The foundation for this initiative is information sharing between existing control and communication systems and a plan to move towards the latest technology for systems integration. The initiative seeks to develop data highway infrastructures (fiber optic networks in most cases) to facilitate site services that are labor intensive and to support automatic process control of various electrical and mechanical systems. Immediate uses for Fermilab include:

- Building system automation
- Pond water system flood and drought control
- Electrical load management and utility metering
- Equipment control and predictive maintenance

Future uses could also include:

- Medical information
- Fire and emergency services
- Video conferencing
- Recreational programs

Addressing mission critical requirements:

Wilson Hall Safety Improvement Project.

Wilson Hall, constructed in 1972, is the central laboratory facility for the Fermilab site. It is a 17-story reinforced concrete building. The great majority of the facility's 515,000 square feet of area is devoted to office space. In addition, the building contains a cafeteria, communications center, medical office, light industrial and shop space and an 800 seat auditorium. The recently completed Wilson Hall safety improvement project was a comprehensive project to improve the structural integrity and working conditions within one of DOE's premier facilities. This improvement project included elimination of safety deficiencies, updates to current code standards and regulatory requirements, modernization of building components that had reached the end of their intended life and general facility improvements, as well as other projects such as the installation of fiber optics. Wilson Hall is one of Fermilab's show case projects for infrastructure modernization through investment of near \$16 million.

Alternative Financing

Third Party Investments (Utility Incentive Program)

As considered in the Office of Science guidance document for this Strategic Facilities Plan, third party investment is anticipated to continue to be a critical component of Fermilab's infrastructure modernization plan. Taking advantage of the innovative opportunity to save operating funds, improve efficiencies and rebuild Fermilab infrastructure through the Utility Incentive Program (UIP) also known as Utility Energy Services Contracts (UESC).

The UIP is a procurement vehicle that allows for alternative financing (third party investment) of energy and water efficiency projects including infrastructure revitalization. Through partnerships with utility companies, efficiency improvements and savings opportunities have been identified and implemented through a turn-key (concept to completion) process. This process considers a site-wide systems life-cycle total-cost-of-ownership assessment as opposed to the more typical reactive equipment by equipment approach. Through this program, Fermilab has developed a site-wide

multi-year improvement program funded by investments from Nicor Gas and Commonwealth Edison utility companies that will be paid back through the savings created from existing operating budgets.

Fermilab has made substantial progress over the past five years in improving infrastructure. Master planning has been completed for the Particle Physics Division and is underway for Technical and Computing Divisions. These efforts will assist in moving Fermilab towards the modernization guidelines presented by the Office of Science. While the most critical utility systems have been improved or repaired, nearly \$40M dollars in existing and projected requirements have been included in this plan.

There are currently no requirements for Office of Science funded environmental restoration or remediation, and no demolition requirements. Fermilab has recently implemented a building reuse policy to ensure that space requirements are met in the most economical manner and operating budgets aren't used for excess space as it may become available.

Needs Funding Chart

\$M	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
GPP	1.5	4.8	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
UIP	6.4	6.4	6.2	5.5	5.5	5.5	5.5	5.5	5.5	2.7		
Maint.*	4.4	4.3	4.6	4.8	4.9	5.1	5.9	6.2	7.0	7.0	7.0	7.0

**Trending towards \$7.0M to meet investment of 1.5% of RPV*

Vetting process for 10-Year plan development (identifying and prioritizing)

The following offers a brief summary of the process used to develop the plan and establish priorities.

- The process started with interpretation of the guidelines based on Fermilab's mission as stated in the Fermilab Institutional Plan and known programmatic changes since the last plan update.

- A review of existing deficiencies from the building inspection program, latest infrastructure assessment and site wide utility energy/water audits (performed under the UIP initiative), was completed to identify new requirements necessary to meet the flexibility and versatility guidelines.

- Collaborative Research and Integrated Workplace requirements were identified that needed integration into the plan. Technology zoning and evolution were determined to be satisfied at the necessary level based on existing and projected mission requirements.

- Brief scope descriptions and order of magnitude cost estimates were developed for the identified requirements and updated for existing infrastructure requirements. Different approaches were

then considered for funding including continuation of third party investment through the Utilities Incentive Program.

- Since Fermilab is basically one large machine and one large office building (Wilson Hall), and since Wilson Hall the multi-year modernization improvement project has completed, the majority of the projects listed in this plan were determined to fall within the utility system category with a focus on reliability. Projects developed from the master-planning efforts now underway will be included in future updates as applicable.

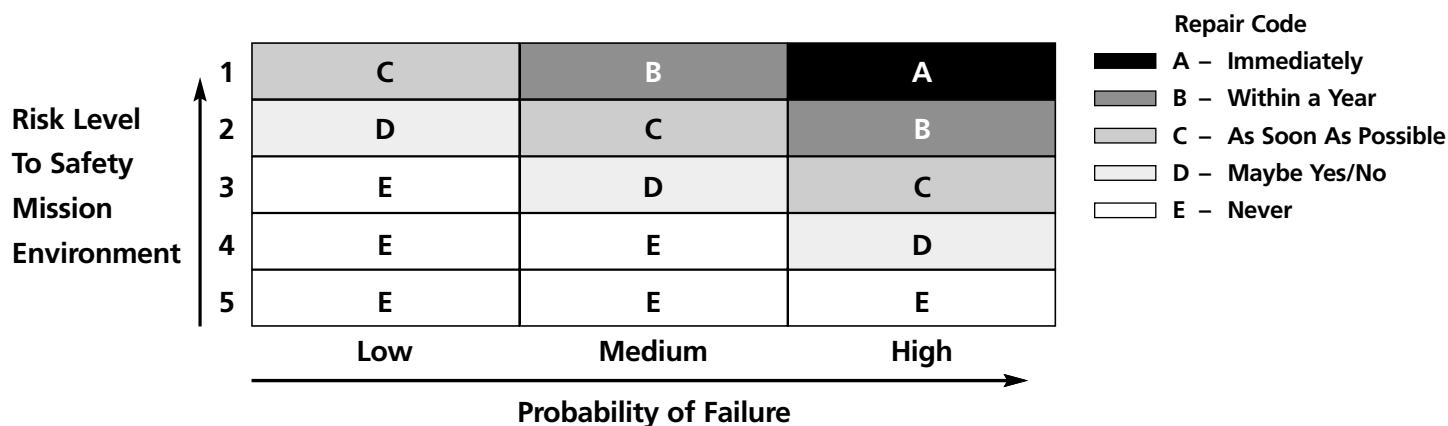
- Prioritization of these utility system projects was based on risk levels associated with safety, mission and environment and the probability of failure of a particular system. Projects were ranked and placed in a particular year for funding.

Criteria

- Safety (is it a threat to personnel safety)
- Vulnerability (is it mission critical)
- Reliability (will its loss impact the mission)
- Redundancy (does the equipment have a back up)

Ranking:

level of risk and probability of failure



Assets Management

"The Laboratory maintains a DOE-approved Property Management System in order to provide acquisition, necessary and appropriate protection, control, use, and disposal of government property. A Balanced Scorecard self-assessment program is used to ensure effective service and partnership, effective life cycle management of assets to meet DOE missions, access to dynamic and strategic information and management systems, and optimum cost efficiency of Property Management Operations." Real Property management of land and improvements involves coordination with new and changing mission of experiments and integration with the Land use plan.

Energy Management and Sustainable Design

Energy management initiatives at Fermilab are in compliance with the recently issued DOE O 430.2A. More specifically

In the **Buildings/Facilities** category FY2001 consumption was 63.18% lower on a Site Use Btu/GSF basis (65.37% lower on a Source Use Btu/GSF basis) than the FY1985 Baseline. Consumption was also 2.72% lower on a Site Use Btu/GSF basis (3.99% lower on a Source Use Btu/GSF basis) than in FY2000. Cost per Unit Energy was 9.92% lower than in FY1985 in spite of abnormally high natural gas costs this year, largely due to fuel switching away from electricity. This addresses the goals of the Fermilab Energy Management Plan Section III paragraph 1 that pertains to Executive Order 13123 Section 202 and DOE Order 430.2 Requirement a.

In the **Industrial/Laboratory** category FY2001 consumption was **34.39% lower** on a Site Use Btu/GSF basis (37.82% lower on a Source Use Btu/GSF basis) than the FY1990 Baseline. Consumption was also **2.03% lower** on a Site Use Btu/GSF basis (0.07% lower on a Source Use Btu/GSF basis) than in FY2000. Cost per Unit Energy was **5.94% lower** than in FY1990 in spite of abnormally high natural gas costs this year, largely due to efficiency improvements. This addresses the goals of the Fermilab Energy Management Plan Section III paragraph 1 that pertains to Executive Order 13123 Section 202 and DOE Order 430.2 Requirement a.

In the **Metered Process** category exemption is being requested for 35% of the lab facilities from the metrics associated with Section 203 of Executive Order 13123 as outlined herein in accordance with the FY2001 reporting guidance.

In the **Vehicles & Equipment** category overall consumption registers as **91.63 % lower** than the FY1991 Baseline consumption due to changes in reporting requirements. These figures reflect equipment consumption only per instructions contained in the *Guidance for FY2001 Annual Energy Management Report* issued by FEMP. Data for passenger fleet motor vehicles is being reported separately on the General Services Administration (GSA) Agency Report of Motor Vehicle Data (Form SF-82). Consumption registers as **50.21% lower** than the FY2000 consumption using the same metrics as FY2001, largely due to facility equipment use requirements throughout the year. This is addressed in the goals of the Fermilab Energy Management Plan Section III paragraph 16, that pertains to Executive Order 13123 Section 405. Cost per Unit Energy was **19.51% higher** than in FY1991 simply due to higher fuel prices.

Awards:

a. In FY2001 Fermilab made cash awards totaling \$3K to two employees for their exceptional performance in the successful execution of the UESC project ECP-X under UIP Delivery Order ECM2000 – Phase N. This was a \$1M retrofit that upgraded a main cryogenic compressor and cooling tower associated with the Central Helium Liquefier (CHL) facility.

b. The lab received a DOE 2001 Departmental Energy Management Award in Washington DC this year for innovative energy technology associated with its new CHL Liquid Nitrogen Recovery Retrofit. Three lab employees and two local DOE employees were allowed to attend the ceremonies honoring this accomplishment. The impact of this retrofit reflects on Metered Process energy efficiency.

c. The lab received a DOE 2001 Departmental Energy Management Award in Washington DC this year for alternative financing energy projects associated with its new ECM2001 – Phase C and Phase N Delivery Orders issued this year. Three lab employees and two local DOE employees were allowed to attend the ceremonies honoring this accomplishment.

d. Four awards were received this year from the Association of Energy Engineers (AEE). One was given to the Fermi Area Office of DOE for developing contractual methods for implementation of the Fermilab UIP program over consecutive years. The three other awards were given to Fermilab for issuing the second set of two UESC Delivery Orders in FY2001 totaling over \$27M which continued energy Audit Master Plan (AMP) implementation, for energy retrofit upgrades to the Feynman Computing Center under ECM2001 – Phase C, and for CHL retrofit upgrades under ECM2000 - Phase N. One lab employee and one DOE employee were allowed to attend the ceremonies honoring this accomplishment.

Utility Services Contracts

This addresses the goals of the *Fermilab Energy Management Plan* Section III paragraph 9 that pertains to Executive Order 13123 Section 403.a and DOE Order 430.2 Requirements.

In addition to past successes, an additional \$27M FY2001 UESC Delivery Orders were awarded to ComEd and Nicor, Fermilabs' electric and gas utility company.

In an effort to enlist their participation in identifying integrated solutions and other savings potentials, the UIP program reached out to all of the Divisions/Sections at the lab to embrace a number of other infrastructure needs not on the original list, which brought in additional rewarding opportunities on the Metered Process side.

Again this year, the most important contribution of the FY2001 UESC Delivery Orders has been the fresh perspective it has continued to give the lab on planning its infrastructure upgrades going forward. Many new solutions and issues have been uncovered which would never have surfaced otherwise. The emphasis has been on building quality systems with maintainability and Sustainable Design principals that reduce future operating costs. Also, a sustained appreciation for the importance of conservation and efficiency in securing future performance has been reinforced throughout the lab culture. It is this awareness and the cooperative efforts of all laboratory Divisions/Sections that will determine the continuing viability and effectiveness of UIP in rebuilding needed infrastructure as we continue to dig deeper into process applications for the maximum savings potential.

Benefits of the FY2001 UESC initiatives include:

1. Identified and implemented Tevatron 95LCW pumping reduction for BD prior to Run II which generate over \$220K in annual energy savings.
2. Identified additional annual energy savings potential and eliminated the need for implementation of a second ICW pump house through value engineering associated with the extension of utilities partially around the Tevatron Ring, which addresses a site vulnerability identified by Factory Mutual and eliminates the need for over \$1.5M in project improvements associated therewith.
3. Identified and implemented numerous additional Value Engineering improvements in the construction of feeders and lift stations, some of which came directly from Utility standard practices.
4. High quality of work on ECPs already constructed has elicited compliments from around the lab.
5. Continued good construction management and safety practices in the field.
6. Lab culture has continued to shift in various Divisions/Sections to look at infrastructure in a global, long-range perspective and to realize the importance of identifying additional energy savings opportunities. This was reinforced by the call for Strategic Facilities Plans from the DOE Office of Science (SC) specifically requesting implementation of alternative financing mechanisms to help rebuild aging infrastructure using sustainable design guidelines, which is what UIP does.
7. Identified additional requirements associated with infrastructure failures and repairs and developed solutions to address these issues.

**Energy Star status
(identify plans and goals
for determining and number
achieved)**

Although none of the buildings on site fit the Energy Star Building benchmark criteria, Fermilab continued to promote efficiency measures through its UIP program, and engineering design specifications. Fermilab has submitted a project to be constructed through its UIP program in ECM2001a – Phase C on Energy STAR building upgrades and certification in its Village area to DOE FEMP for funding under its FY2001 *Energy Retrofit Projects* initiative. It will also continue to monitor the Energy Star program for new developments. This addresses the goals of the *Fermilab Energy Management Plan* Section III paragraph 15 that pertains to Executive Order 13123 Section 403.c and d.

Summary

The Fermilab Strategic Facilities Plan brings together modernization guidelines and existing infrastructure requirements to identify in a comprehensive manner all known needs to continue towards achieving recognition as a “model” Office of Science laboratory for the 21st century. This Strategic Facilities Plan focuses on rebuilding Fermilab to best satisfy the current mission requirements while considering the various future activities that could be satisfied through infrastructure that has some of the highest utility reliability (and capacity) in the SC laboratory complex.

Most significant are the completion of the Wilson Hall improvement project and the Fermilab third party investment successes through the Utility Incentive Program.

Use of such programs has the potential to reduce overall revitalization costs by creating a platform for detailed infrastructure analysis in conjunction

with utility company expertise, while creating real incentives to reduce costs and maximize return on investment. One of the advantages of using third party funding is that it allows immediate implementation of detailed infrastructure assessments and optimization planning together with initial renovation work at relatively low costs. This could allow more time for SC to develop direct funding sources without delaying critical infrastructure needs.

The identification and prioritization process that is described in this plan is one of several ongoing management initiatives used to develop this plan. These initiatives will continue to be critical management components for ensuring Fermilab continues to be operated and maintained with the focus of sustainability through flexibility and versatility thereby ensuring taxpayer investments continue to be used to create the highest value and associated contribution to science.

Table 11. Major Construction Projects (\$ in Millions)

	TEC	FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08
Funded Construction									
Program Line Item Projects									
NuMI Project	109.2	22.9	11.4						
General Plant Projects (KA)		3.0	1.4						
Accelerator Improvement Projects (KA)		4.9	3.8						
Total Funded		30.8	16.6	0.0	0.0	0.0	0.0	0.0	0.0
Budgeted Construction									
Program Line Items									
NuMI Project				20.1	12.5	0.5			
General Plant Projects (KA)									
Accelerator Improvement Projects (KA)									
Total Budgeted		0.0	0.0	20.1	12.5	0.5	0.0	0.0	0.0
Total Funded and Budgeted		30.8	16.6	20.1	12.5	0.5	0.0	0.0	0.0
Proposed Construction									
Program Line Items									
General Plant Projects (KA)				4.8	5.5	5.5	5.5	5.5	5.5
Accelerator Improvement Projects (KA)				8.5	8.6	12.8	10.6	9.4	9.5
Total Proposed		0.0	0.0	13.3	14.1	18.3	16.1	14.9	15.0
Total Funded, Budgeted, and Proposed		30.8	16.6	33.4	26.6	18.8	16.1	14.9	15.0

Resource Projections

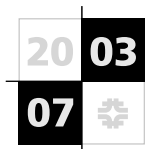


Table 2. Laboratory Funding Summary (\$ in Millions)						
	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008
DOE Effort						
Fermilab	215.4	222.1	236.0	248.3	263.7	270.6
LHC	11.1	8.2	10.3	10.0	10.0	10.0
Work for Others	0.2	0.2	0.2	0.2	0.2	0.2
TOTAL OPERATING	226.7	230.5	246.5	258.5	273.9	280.8
Capital Equipment						
Program Capital Equipment	28.6	32.3	33.2	34.1	34.9	35.7
LHC Capital Equipment	12.3	12.9	12.0	9.9	2.5	2.5
Subtotal	40.9	45.2	45.2	44.0	37.4	38.2
Program Construction						
NuMI	20.1	12.5	0.5	0.0	0.0	0.0
AIP/GPP	13.3	14.1	18.3	16.1	14.9	15.0
Subtotal	33.4	26.6	18.8	16.1	14.9	15.0
TOTAL LABORATORY FUNDING	301.0	302.3	310.5	318.6	326.2	334.0

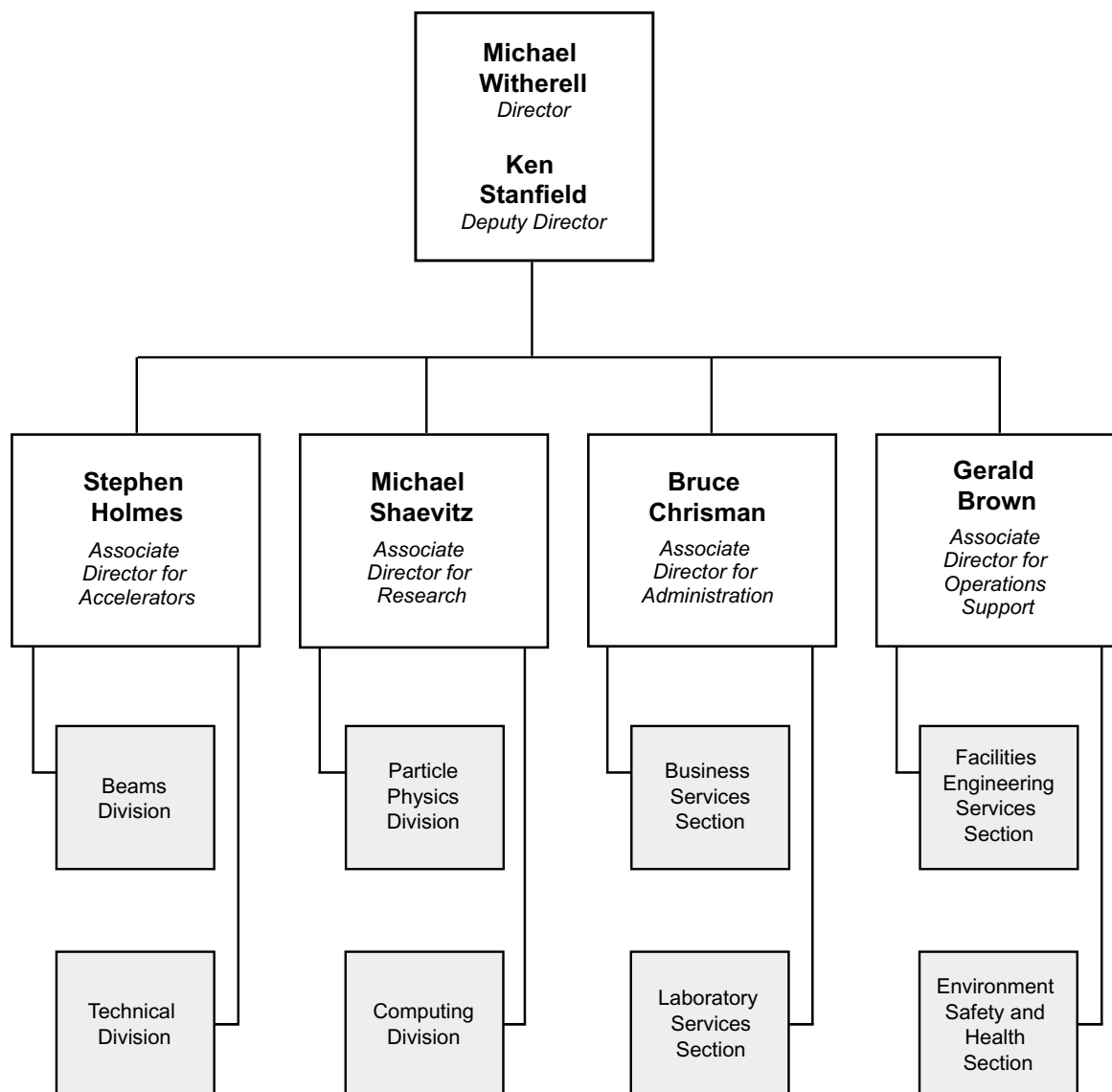
Table 4. Resources by Major DOE Program (\$ in Millions) (Personnel in FTE)						
Program	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008
KA - High Energy Physics						
Operating (2)	223.2	226.8	242.7	254.6	269.9	276.7
Capital Equipment	40.9	45.2	45.2	44.0	37.4	38.2
Construction	33.4	26.6	18.8	16.1	14.9	15.0
Total KA	297.5	298.6	306.7	314.7	322.2	329.9
Program 60 - Work for Others						
Operating	0.2	0.2	0.2	0.2	0.2	0.2
Miscellaneous						
Operating (3)	3.3	3.5	3.6	3.7	3.8	3.9
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0
Total Misc.	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1,741	1,741	1,741	1,741	1,741	1,741

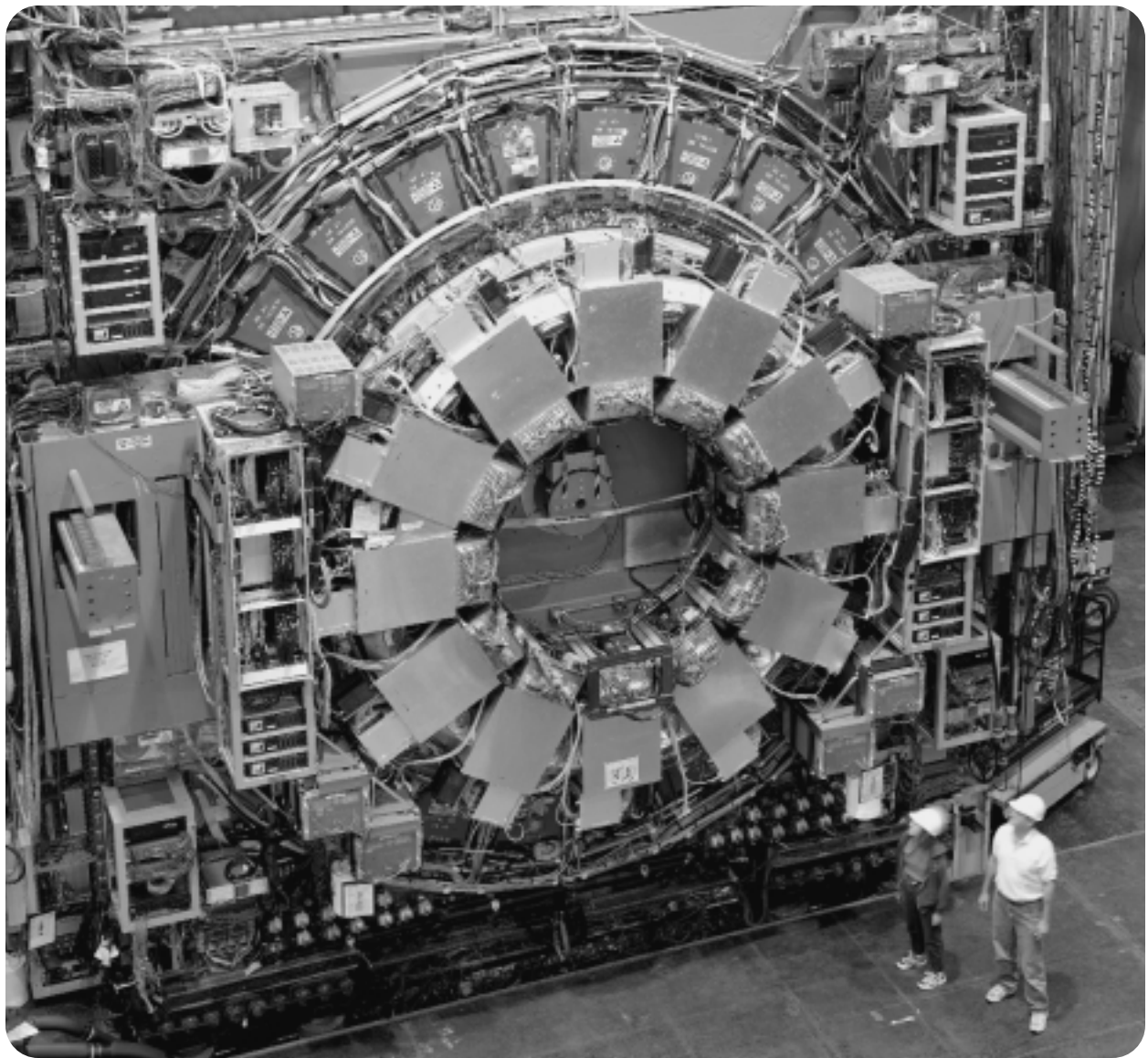
Table 4a. Funding by Activity Use millions of dollars, rounded to one decimal place						
	FY '03	FY '04	FY '05	FY '06	FY '07	FY '08
R&D and Operations	226.7	230.5	246.5	258.5	273.9	280.8
Construction	33.4	26.6	18.8	16.1	14.9	15.0
Capital	40.9	45.2	45.2	44.0	37.4	38.2
Non-DOE Funds						
External Performers						
Total	301.0	302.3	310.5	318.6	326.2	334.0

Supplemental Information



Fermilab Directorate Organization Chart





Project co-managers Bob Kephart (right) and Cathy Newman Holmes surveyed the upgraded CDF detector before it was rolled in to the collision hall for Run II of the Tevatron.

**Supplemental Table 3
EEO Utilization Analysis Within Major Job Groups**

Total Laboratory 31-May-02		MALE				FEMALE														
	US SOC Total	Male	Female	Black Male	Asian Male	Amer Indian Male	Hisp. All Oth Male	His/Lat White Male	Ha/Pac Islander Male	Black Female	Asian Female	Amer. Indian Female	Hisp. All Oth Female	His/Lat White Female	Ha/Pac Islander Female	Total Minority	Total Female	Avail. Percent Minority	Avail. Utilization Female	Under Female
Officials and Managers	Executives and Managers	Percent 0.7	137 0	27 0	19.7 0	0 0	3 7.3	2.20 27	0.0 14.3	0 YES	0.0 YES	0.7 0	1 0	1 0	0.7 0	3 3	2.21 0	0.7 0	0.0 0	1 1
	Unit Supervisors	Percent 1.1	88 0	79 0	10.2 0	4 0	4.5 9.1	1 10.2	0.0 90.0	1 NO	1.1 NO	0.0 0	0 0	0 0	0.0 0	1 1	1.10 0	0.0 0	0.0 0	1 1
	Skilled Supervisors	Percent 0.0	21 0	18 0	3 0	14.3 5	23.8 0	14.3 30.0	0.01 4.8	0 NO	0.0 NO	4.8 1	0 0	0 0	0.0 0	0 0	0.00 0	0.0 0	0.0 0	0 0
Total Officials and Managers Percent		246	207	39 15.9	7 2.8	4 1.6	1 0.4	2 0.8	1 0.4	4 1.6	1 0.4	0 0.0	2 0.8	0 0.0	0 0.0	23 9.3	39 15.9			
Professionals																				
Administrative Support		Percent 3.1	131 3	43 2.3	67.2 0	3 0	2.3 17.6	1 67.2	0.0 880.0	1 NO	0.0 NO	0.0 0	0 0	0 0	0.0 0	6 6	4.65 3.8	0 0.0	0.0 0	4 4
Engineering Physicists		Percent 0.0	68 0	61 0	7 0	10.3 0	4 7	5.9 10.3	0.0 40.0	0 NO	0.0 NO	0.0 0	0 0	0 0	0.0 0	0 0	0.00 0.0	0.0 0	0.0 0	0 0
Physicists		Percent 0.4	228 0	207 0	21 0	9.2 0	1 0	0.4 11.4	18 7.90	3 YES	1.3 YES	0.0 0	0 0	0 0	0.0 0	0 0	0.03 1.3	0 0.0	0.0 0	1 1
Research Associates		Percent 0.5	205 1	170 0.5	35 0	17.1 0	0 49	0.0 23.9	15.10 17.1	3 NO	1.5 NO	2.4 5	0 0	0 0	0.0 0	0 0	0.08 3.9	0 0.0	0.0 0	1 1
Engineering/Elec./Mech.		Percent 0.0	215 0	203 0	12 0	5.6 0	5 39	2.3 18.1	8.80 120.0	8 NO	3.7 YES	1.9 4	0 0	0 0	0.0 0	0 0	0.03 1.4	0 0.0	0.0 0	0 0
Computing		Percent 1.5	198 0	150 0	48 0	24.2 0	5 34	2.5 17.2	8.10 480.0	2 NO	1.0 NO	0.0 0	0 0	0 0	0.0 0	1 1	0.57 3.5	0 0.0	0.0 0	3 3
Technical Aides		Percent 1.3	149 0	138 0	11 0	7.4 0	10 17	6.7 11.4	0.70 1119.1	2 YES	1.3 YES	0.7 1	0 0	0 0	0.0 0	1 1	0.70 0.0	0 0.0	0.0 0	2 2
Total Professionals Percent			1,194	972	222 18.6	28 2.3	89 7.5	0 1.6	10 0.8	8 0.7	26 2.2	0 0.0	11 0.9	4 0.3	0 0.0	195 16.3	222 18.6			
Technicians																				
Drafting		Percent 0.0	43 0	36 0	7 0	16.3 0	4 6	9.3 14.0	2.30 70.0	1 NO	2.3 NO	0.0 0	0 0	0 0	0.0 0	0 0	0.00 0.0	0 0.0	0.0 0	0 0
Technicians/Elec./Mech.		Percent 2.7	369 2	310 0.5	59 0	16.0 0	26 75	7.0 20.3	2.71 590.0	18 NO	4.9 NO	0.5 2	0 0	0 0	0.0 0	6 6	1.60 0.0	0 0.0	0.0 0	10 10
Operations Support		Percent 2.4	41 0	34 0	7 0	17.1 0	3 8	7.3 19.5	1 2.40	0 NO	0.0 NO	0.0 0	0 0	1 1	2.4 2	2 2	4.90 0.0	0 0.0	0.0 0	1 1
Total Technicians Percent			453	380	73 16.1	33 7.3	12 2.6	1 0.2	2 0.4	8 1.8	0 0.0	0 0.0	11 2.4	2 0.4	0 0.0	89 19.6	73 16.1			

Supplemental Table 4a. Laboratory Personnel Summary

(Personnel Headcount at Fiscal Year End*)

	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008
Direct	1,694.0	1,703.0	1,741.0	1,741.0	1,741.0	1,741.0	1,741.0	1,741.0
Indirect	495.0	496.0	507.0	507.0	507.0	507.0	507.0	507.0
Total Laboratory	2,189.0	2,199.0	2,248.0	2,248.0	2,248.0	2,248.0	2,248.0	2,248.0

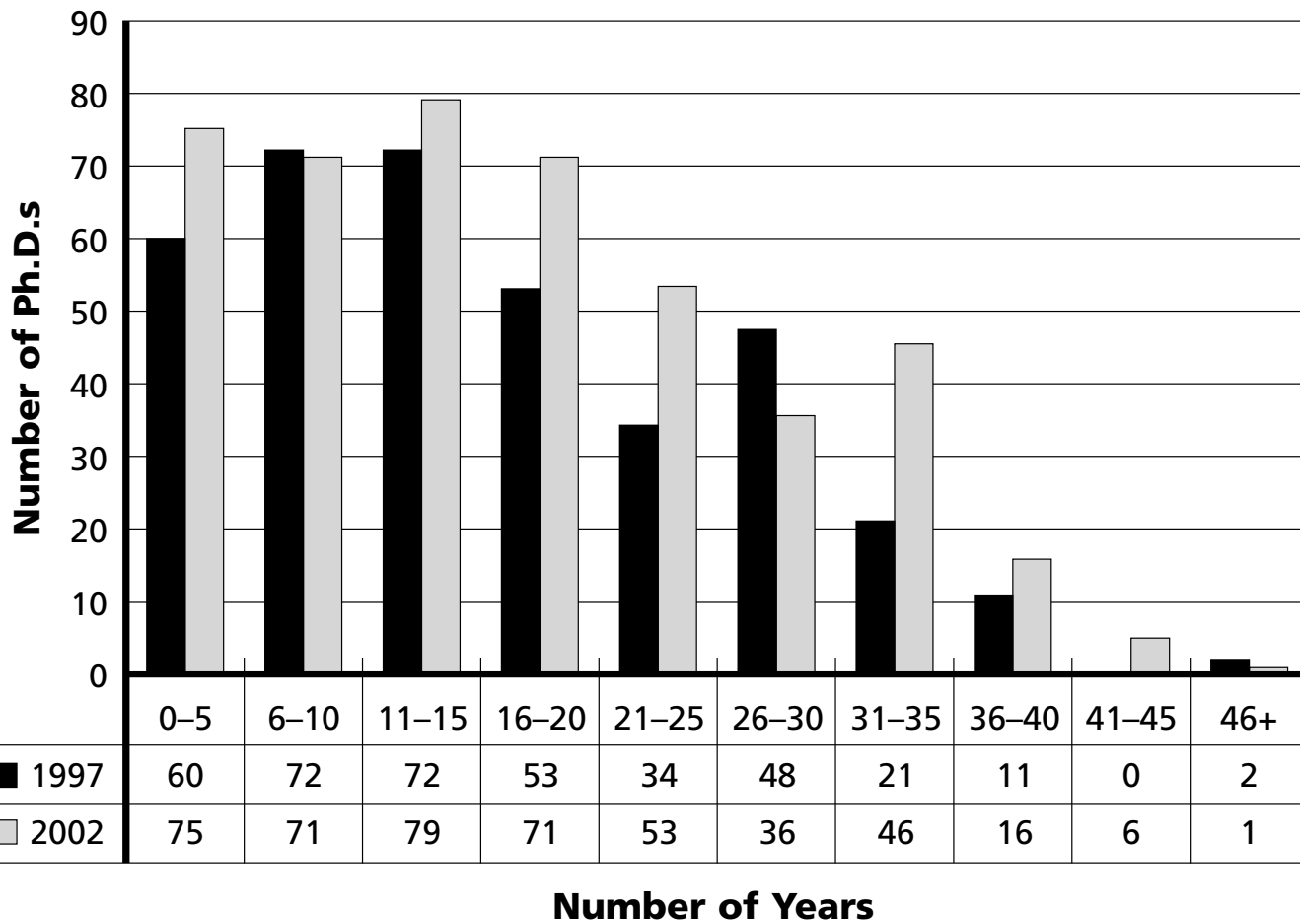
*Includes permanent and guest scientists, temporary and part time employees, and excludes employees on leave of absence

Supplemental Table 4b. Fermilab Staffing Summary, 1993-2002

1/1/1993 through 1/1/2002

	2002	2001	2000	1999	1998	1997	1996	1995	1994	1993	Change '02-'93
Engineer and Scientists	738	720	700	663	626	613	619	610	616	616	122
Technicians and Tech Support	623	634	650	659	663	681	711	740	792	819	-196
Computer Professionals	264	236	225	209	191	185	187	183	189	196	68
Other	561	560	576	563	547	572	611	618	674	685	-124
Total Lab	2186	2150	2151	2094	2027	2051	2128	2151	2271	2316	-130

Supplemental Table 4c.
Distribution of Fermilab Ph.D.'s, 1997 and 2002



Supplemental Table 5: Subcontracting and Procurement

(\$ in millions obligated within each fiscal year)

	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Subcontracting and procurement from:					
Universities	10.0M	15.6M	18.0M	19.9M	15.0M
All Others	118.5M	110.6M	127.5M	102.1M	107.7M
Transfers to other DOE Facilities	1.0M	1.3M	0.5M	2.4M	1.3M
Total External Subcontracts and Procurement	\$129.5M	\$127.5M	\$146.0M	\$124.4M	\$124.0M

Supplemental Table 6: Small and Disadvantaged Business Procurement

	FY98	FY99	FY00	FY01	FY02
Small and Disadvantaged Business Procurement (\$ in millions—B/A)					
Total Procurement from S&DB	72M	68M	65M	44M	45M
% of Annual Procurement	64	56	56	48	50

Supplemental Table 7: Fermilab Users in 2002—Totals

A. U.S.	Physicists	Students	Subtotal	Institutions
University	721	398	1119	94
National Lab	386	16	402	7
Sub Total	1107	414	1521	101
B. Non-U.S.				
University	468	178	646	90
National Lab	301	36	337	23
Sub Total	769	214	983	113
TOTAL	1876	628	2504	214

Supplemental Table 8: Education '01

Program	Part S	Par T	#Min	#Fem
FERMILAB				
Cryogenic Show	5211			
Daughters and Sons to Work	250			
Fermilab ARISE		25	3	11
Fermilab LInC Facilitators' Academy		33	3	21
Fermilab LInC Online		70	4	41
Fermilab Teacher Fellowship		1		
Lederman Center	4126			
Museum Partners		40	38	36
Phriendly Physics		8	1	7
Physics Science Experience	2087	25		
Prairie Science Experience	7671	96		
Professional Networks		1605		
QuarkNet Research		16		4
QuarkNet Institutes		116		
QuarkNet Follow-on		111		
Saturday Morning Physics	356			
Science Adventures	1288			
sciencelines		2000		
Target	18		18	5
Teacher Resource Center		449		
Tours	3087	174		
TRAC		7?	?	
Workshops/Presentational		1622		
Totals	24,094	6,398		

Supplemental Table 8A: Education: Minority Programs

	FY 2000:			FY 2001:		
Pre-College Programs	Total	Minorities	Women	Total	Minorities	Women
Student Programs: TARGET	18	18	5	15	15	7
Undergraduate Programs						
Student Programs: Summer Internships	18	18	7	17	15	5
in Science and Technology						
Graduate Programs						
Student Programs: GEM PhD	5	5	1	3	3	2
fellowships for minority students						



The DZero collaboration at Fermilab numbers nearly 600 scientists, symbolizing both the complexity and the international nature of particle physics experiments.

Recommendations

of the

DEPARTMENT OF ENERGY/
NATIONAL SCIENCE FOUNDATION
HIGH-ENERGY PHYSICS ADVISORY PANEL

SUBPANEL ON LONG RANGE PLANNING
FOR U.S. HIGH-ENERGY PHYSICS

January 2002

RECOMMENDATION 1:

We recommend that the United States take steps to remain a world leader in the vital and exciting field of particle physics, through a broad program of research focused on the frontiers of matter, energy, space and time.

The U.S. has achieved its leadership position through the generous support of the American people. We renew and reaffirm our commitment to return full value for the considerable investment made by our fellow citizens. This commitment includes, but is not limited to, sharing our intellectual insights through education and outreach, providing highly trained scientific and technical manpower to help drive the economy, and developing new technologies that foster the health, wealth and security of our nation and of society at large.

RECOMMENDATION 2:

We recommend a twenty-year roadmap for our field to chart our steps on the frontiers of matter, energy, space and time. The map will evolve with time to reflect new scientific opportunities, as well as developments within the international community. It will drive our choice of the next major facility and allow us to craft a balanced program to maximize scientific opportunity.

We recommend a new mechanism to update the roadmap and set priorities across the program. We understand that this will require hard choices to select which projects to begin and which to phase out. Factors that must be considered include the potential scientific payoff, cost and technical feasibility, balance and diversity, and the way any proposed new initiative fits into the global structure of the field.

RECOMMENDATION 3:

We recommend that the highest priority of the U.S. program be a high-energy, high-luminosity, electron-positron linear collider, wherever it is built in the world. This facility is the next major step in the field and should be designed, built and operated as a fully international effort. We also recommend that the United States take a leadership position in forming the international collaboration needed to develop a final design, build and operate this machine. The U.S. participation should be undertaken as a partnership between DOE and NSF, with the full involvement of the entire particle physics community. We urge the immediate creation of a steering group to coordinate all U.S. effort toward a linear collider.

RECOMMENDATION 4:

We recommend that the United States prepare to bid to host the linear collider, in a facility that is international from the inception, with a broad mandate in fundamental physics research and accelerator development. We believe that the intellectual, educational and societal benefits make this a wise investment of our nation's resources.

We envision financing the linear collider through a combination of international partnerships, use of existing resources, and incremental project support. If it is built in the U.S., the linear collider should be sited to take full advantage of the resources and infrastructure available at SLAC and Fermilab.

RECOMMENDATION 5:

We recommend that vigorous long-term R&D aimed toward future high-energy accelerators be carried out at high priority within our program. It is also important to continue our development of particle detectors and information technology. These investments are valuable for their broader benefits and crucial to the long-range future of our field.



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